NOTICE

All drawings located at the end of the document.

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Source Evaluation Report for Point of Evaluation SW093

Revision 0

November 1999

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Golden, Colorado

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1. EXECUTIVE SUMMARY

Rocky Flats Environmental Technology Site personnel have completed a source evaluation related to the cause(s) of elevated 30-day moving averages for plutonium[1] at the Walnut Creek Rocky Flats Cleanup Agreement (RFCA) Point of Evaluation (POE) monitoring location SW093. First reported on September 15, 1999, elevated 30-day moving average values have been observed at the POE monitoring location 1300 feet above Pond A-1 (referred to as SW093) for the period July 25 through August 3, 1999. RFCA requires a source evaluation for POEs when specific constituents are measured above Action Levels; this Report fulfills that requirement.[2]

This Source Evaluation Report builds on the results of the completed Reports (RMRS, 1997c, 1997d, 1997e, 1998a) for the *Plan for Source Evaluation and Preliminary Proposed Mitigating Actions for Walnut Creek Water-Quality Results* (RMRS, 1997b). Site personnel have evaluated historical data, collected additional water samples for analyses, and assessed Site activities as part of this source evaluation. Site personnel have concluded that the likely source of the elevated measurements of the 30-day average for plutonium at SW093 is diffuse, low-level radionuclide contamination released to the environment from past Site operations. The best evidence indicates that the most significant source area of this contamination appears to be the Building 779 sub-drainage.

Specifically, this Report concludes the following:

- Recent surface-water sampling results from tributary monitoring locations have further refined the estimation of relative plutonium load contributions to SW093 from upstream sub-drainage areas;
- The Building 779 sub-drainage (monitored by location GS32) may be a significant contributor of actinide loads to SW093;
- Readings from *in-situ* water-quality monitoring probes indicate no unusual or unexpected conditions for WY99 to date;
- Evaluations of recent Site activities suggest that neither D&D, ER, excavation, nor routine operations during the event period caused a release of plutonium or americium that resulted in the elevated activities measured at SW093; and

[1] In this report, 'plutonium' refers to Pu-239,-240 and 'americium' refers to Am-241.

[2] The RFCA requires reporting "when contaminant concentrations in Segment 5 exceed the Table 1 action levels" and that "source evaluation will be required". Further, RFCA states "if mitigating action is appropriate, the specific actions will be determined on a case-by-case basis, but must be designed such that surface water will meet applicable standards at the POCs" (Points of Compliance).

- The elevated values observed at SW093 and other monitoring locations in the SW093 drainage are not being observed at the Ponds or downstream POCs.

This Report contains no specific recommendations for source control due to the reportable values measured at SW093.[3] In addition, no specific remedial actions are required, nor is mitigation needed to protect water quality at any POC identified under RFCA.

As part of our ongoing efforts to close the Site in a safe and environmentally responsible manner, the Site will:

1. Continue it's extensive program of routine monitoring, analysis, and reporting to improve our understanding of potential diffuse source impacts to surface water;

2. Continue to provide progress reporting through Quarterly RFCA Reports, Quarterly State Exchange Meetings, AME reports, and informal status/flash briefs as needed.

3. Continue progress on the Actinide Migration Evaluation (AME) as a longer-term technical study to provide more specific understanding and insight about the cause(s) and possible effective mitigation measures to prevent reportable radionuclide water-quality measurements; and

4. Continue to develop and refine the soil characterization strategy within the Industrial Area Strategy, as needed to protect surface water following final remediation of the Industrial Area (IA).

2. INTRODUCTION

This Source Evaluation Report is provided in accordance with the *Final Rocky Flats Cleanup Agreement* (RFCA) (CDPHE et al., 1996) (Attachment 5, §2.4(B)) under "Action Determinations". The RFCA requires reporting "when contaminant concentrations in Segment 5 exceed the Table 1 action levels" and that "source evaluation will be required". Further, RFCA states "if mitigating action is appropriate, the specific actions will be determined on a case-by-case basis, but must be designed such that surface water will meet applicable standards at the POCs" (Points of Compliance).

Specifically, this source evaluation addresses the September 15, 1999 Rocky Flats Environmental Technology Site (Site) report of elevated 30-day moving averages for plutonium water-quality results at the Point of Evaluation (POE; Segment 5) monitoring location 1300 feet above Pond A-1[4] (referred to as SW093) in North Walnut Creek. Elevated values for plutonium were measured for the period July 25 through August 3, 1999. This Source Evaluation Report builds on the results of the completed Reports (RMRS, 1997c, 1997d, 1997e,

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[3] Future Site Closure and environmental remediation activities already scheduled for the Site may positively influence water-quality at SW093. Remediation and mitigation actions for the B779 sub-drainage will be considered after demolition is completed this year.

[4] Flows from SW093 bypass Ponds A-1 and A-2 via the A-Series Bypass, and flow to Pond A-3, and subsequently to Pond A-4 through managed release.

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1998a) for the *Source Evaluation and Preliminary Proposed Mitigating Actions for Walnut Creek Water-Quality Results* (RMRS, 1997b). This Plan was delivered to the Colorado Department of Public Health and the Environment (CDPHE), the Environmental Protection Agency (EPA), the City of Broomfield and the City of Westminster, on September 15, 1997.

This Report for Walnut Creek gaging station SW093 covers data received by the Site through October 8, 1999. The following is included in this Report:

- Results and analysis of ongoing, automated surface-water monitoring data including trending and correlations, statistical analysis, and loading analysis;
- A review of existing soil/sediment data;
- An assessment of Decontamination and Decommissioning (D&D), Environmental Restoration, and Site Closure projects; and
- A summary of current Actinide Migration Evaluation findings.

3. BACKGROUND

3.1. SITE HYDROLOGY

Walnut Creek, the subject of this investigation and one of several Site drainages, flows east beyond the Site's boundary at Indiana Street. Downstream of Indiana Street, flows are diverted around Great Western Reservoir via the Broomfield Diversion Ditch, and back to Walnut Creek. Walnut Creek then flows into Big Dry Creek, and on to the South Platte River.

Walnut Creek Tributaries

Upstream from Indiana Street, Walnut Creek receives flow from the following four tributaries (listed here in order from north to south and shown in Figure 3-1):

- McKay Bypass Canal (Coal Creek water conveyance canal);
- No Name Gulch (buffer zone drainage basin east of the Landfill Pond);
- North Walnut Creek (northern IA drainage basin); and
- South Walnut Creek (central IA drainage basin).

No Name Gulch and the McKay Bypass Canal receive runoff only from non-IA drainage basins, and typically flow only during the spring or following large storm events, and are not controlled by detention ponds. The McKay Bypass Canal is also used by the City of Broomfield to transfer water from Coal Creek to Great Western Reservoir. North and South Walnut Creek, in contrast, both have nearly continuous baseflow, receive runoff from the IA, and are controlled by a system of detention ponds. A discussion follows describing how water runs off the IA, into North and South Walnut Creeks, through the detention pond network, and, ultimately, into Walnut Creek where it flows offsite at Indiana Street.

North and South Walnut Creek Flow Controls

All IA surface-water runoff that flows into North or South Walnut Creek is collected by a system of Site stormwater detention ponds. The ponds serve three main purposes for surface-water management: (1) storm water detention and settling of sediments, (2) water storage for sampling and, if necessary, treatment prior to discharge, and (3) emergency spill control in those instances where a spill cannot be adequately managed without use of the ponds.

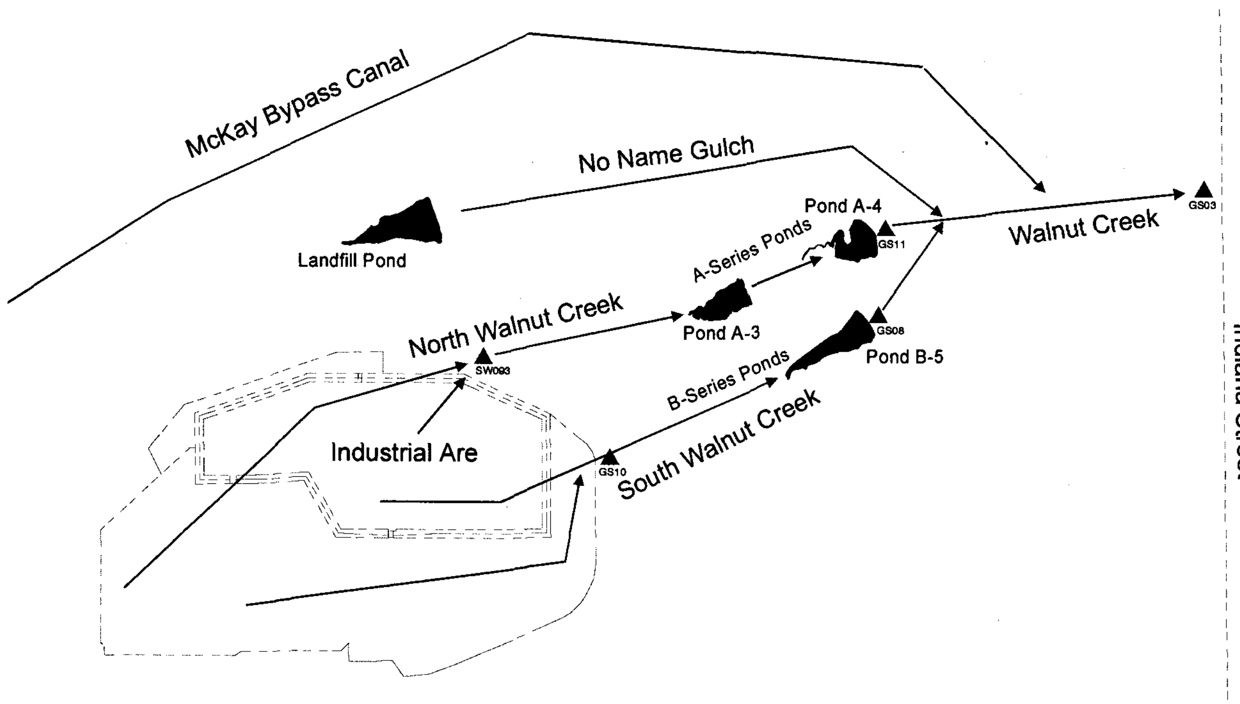

Figure 3-1. Hydrologic Connectivity of Site Drainage and Water Management Features.

North Walnut Creek water is routed through the A-Series ponds (Figure 3-1). Steps in the water collection and transfer process are summarized as follows:

- Runoff from the northern Industrial Area flows directly to SW093;
- Runoff from SW093 flows downstream into Pond A-3 via the A-1 Bypass (bypassing Ponds A-1 and A-2);
- Water is held in Pond A-3, then periodically (≈ 9 times per year) released in batches into Pond A-4; and
- After Pond A-4 is filled to about 50% of capacity, flows from Pond A-3 are discontinued thereby isolating the Pond A-4 water from the rest of the pond network. A sample of the Pond A-4 water is collected and

analyzed by CDPHE, and if sample results indicate water quality standards are met, the "batch" of water is discharged through the outlet works of Pond A-4. Samples are collected of the Pond A-4 discharge water, at station GS11, and the water flows on to Walnut Creek and station GS03. These batch releases from Pond A-4 occur from 6 to 12 times per year, depending on the amount of precipitation received at the Site, and involve approximately 100 to 200 million gallons of water annually.

As indicated above, all of the IA runoff that flows into North Walnut Creek is ultimately routed through Pond A-4, detained, and sampled prior to being released to lower Walnut Creek. There is no source of IA runoff that can enter Lower Walnut Creek without first passing through the pond system for discharge from Pond A-4. Downstream from Pond A-4, the only sources of surface-water entering Walnut Creek upstream of the Site boundary are South Walnut Creek (through Pond B-5), No Name Gulch, the McKay Bypass Canal, or overland runoff directly into Walnut Creek.

3.2. SW093 MONITORING RESULTS

As specified in the *Integrated Monitoring Plan* (IMP; Kaiser-Hill, 1999), the Site's Water Operations group evaluates 30-day moving averages[5] for selected radionuclides at gaging station SW093. SW093 receives flow from the northern IA and monitors flow to North Walnut Creek via the A-1 Bypass pipeline to Pond A-3 which subsequently flows into Pond A-4. Recent evaluations of water-quality measurements at POE surface-water monitoring location SW093 (located on North Walnut Creek 1300 feet above Pond A-1; see Figure 3-2) show values above the RFCA POE Standards and Action Level Framework value of 0.15 pCi/L for plutonium. Results for recent 30-day moving averages using available data at SW093 are summarized below in Table 3-1 and are plotted in Figure 3-3.

Table 3-1. Recent Water Year 1999 Water-Quality Information from SW093.

Location	Parameter	Date(s) 30-Day Average Above 0.15 pCi/L	Date(s) of Maximum 30-Day Average	Maximum 30-Day Average (pCi/L)	Volume-Weighted Average for WY99 to Date (pCi/L)[a]
SW093	Pu-239,-240	7/25/99 – 8/3/99	7/31/99	0.247	0.039

[a] Includes all data that have been received from analytical labs as of 10/8/99.

[5] The 30-day moving average activity (pCi/L) for a particular day is calculated as a volume-weighted average for a 'window' of time containing the previous 30-days which had flow. The equation can be written as follows:

$$\frac{\sum_{day=1}^{day=-30}[picocuries]}{\sum_{day=1}^{day=-30}[liters]} = 30 - Day\ Average_{day=1}[pCi/L]$$

When a negative result is returned from the lab due to blank correction, a value of zero pCi/L is used in the calculations. Therefore, there are 365 x 30-day moving averages for a location that flows all year (366 in a leap year). For days where no activity is available, either due to failed laboratory analysis or non-sufficient quantity for analysis (NSQ), no 30-day average is reported.

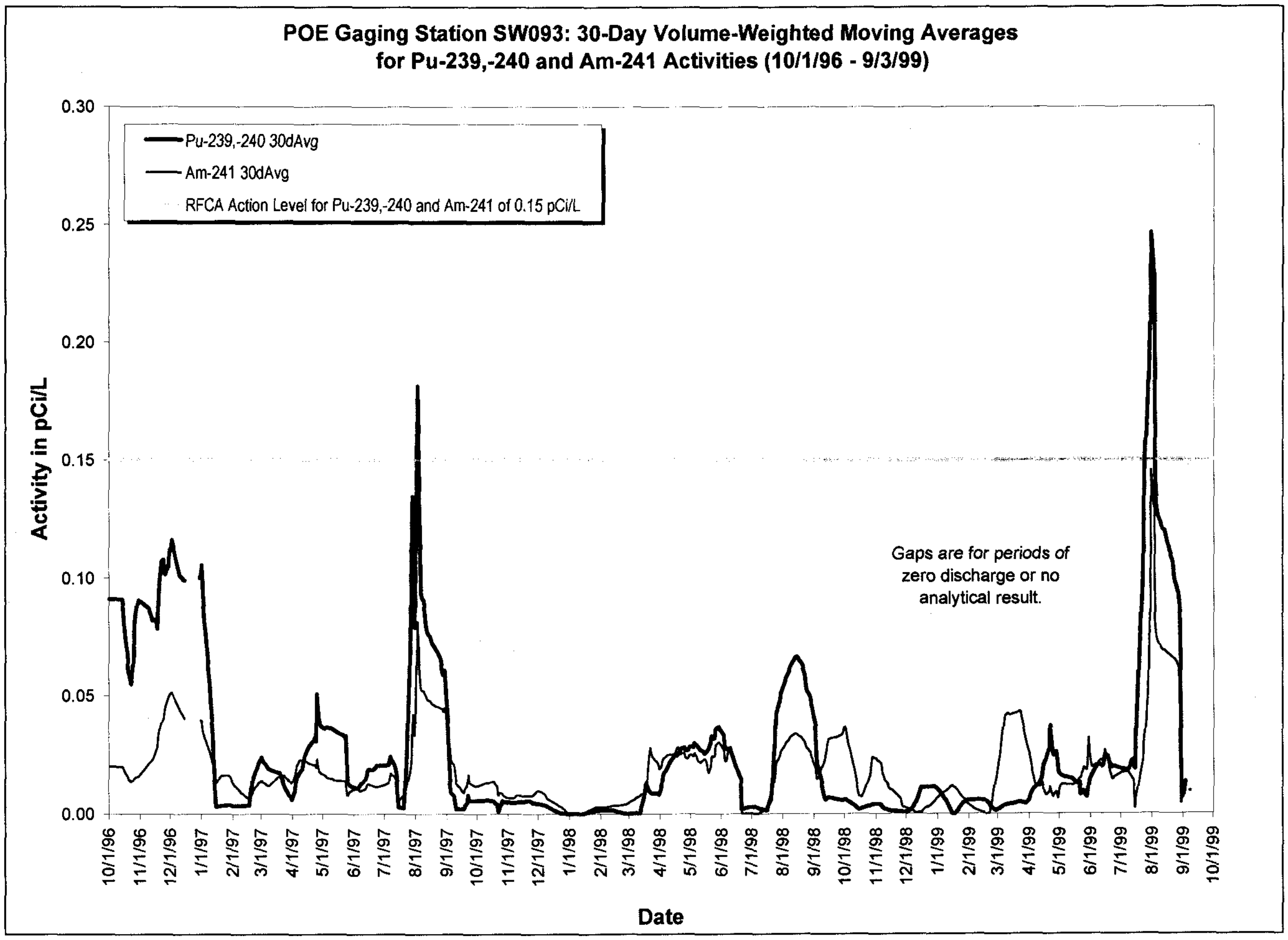

Figure 3-3. Gaging Station SW093 30-Day Averages: October 1, 1996 – September 3, 1999.

The elevated analytical results for the composite samples collected around the period of elevated 30-day average values have been verified. A review of historical monitoring data shows that these results are not unusual. Storm-event[6] samples collected at SW093 from Water Year[7] 1993 (WY93) through WY96 (under pre-RFCA protocols[8]) had an arithmetic average plutonium activity of 0.734 pCi/L with a maximum of 5.3 pCi/L. For the same period, the arithmetic average americium activity was 0.356 pCi/L with a maximum of 1.621 pCi/L. Additionally, during the period of continuous flow-paced monitoring under RFCA, there has been a previous occurrence with reporting and evaluation of 30-day averages above 0.15 pCi/L for plutonium (Figure 3-3). The

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[6] Storm-event samples are generally flow-paced composites consisting of 15 grab samples taken during a direct runoff hydrograph. The grab samples are targeted to be taken on the rising limb. This type of sampling was performed at SW093 from April 1993 through 9/30/96.

[7] A Water Year is defined as the period from October 1 through September 30.

[8] Currently under RFCA, samples collected at POEs are continuous flow-paced composites, where grab samples are collected during all flow conditions. This type of sampling began at POEs and POCs on 10/1/96.

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elevated measurements generally occur during periods of increased stormwater runoff in the spring and summer months (Figure 3-4). Individual composite-sample results and detail for SW093 are listed in Table 3-2 and plotted in Figure 3-5 for the period of interest.

Table 3-2. Composite Sample Analytical Results for SW093: June 24 – September 4, 1999.

Composite Sample Period	Pu-239,-240 (pCi/L)		Am-241 (pCi/L)		Composite Sample Volume (liters)	N. Walnut Cr. Discharge Volume During Sample Period (Mgals)
	Result	2σ Error (±)	Result	2σ Error (±)		
6/24 – 7/2/99	-0.003	0.005	0.002	0.012	7.60	0.38
7/2 – 7/15/99	0.005	0.012	-0.003	0.003	11.8	0.59
7/15 – 7/26/99	0.312	0.098	0.069	0.043	16.2	0.85
7/26 – 8/1/99	0.271	0.093	0.188	0.073	22	3.76
8/1 – 8/4/99	0.081	0.047	0.006	0.014	21.6	2.27
8/4 – 8/31/99	0.003	0.006	0.004	0.012	23.6	5.27
8/31 – 9/4/99	0.051	0.036	0.037	0.031	16.2	0.96

Note: The negative sample results are used as 0.0 pCi/L to calculate the 30-day averages.

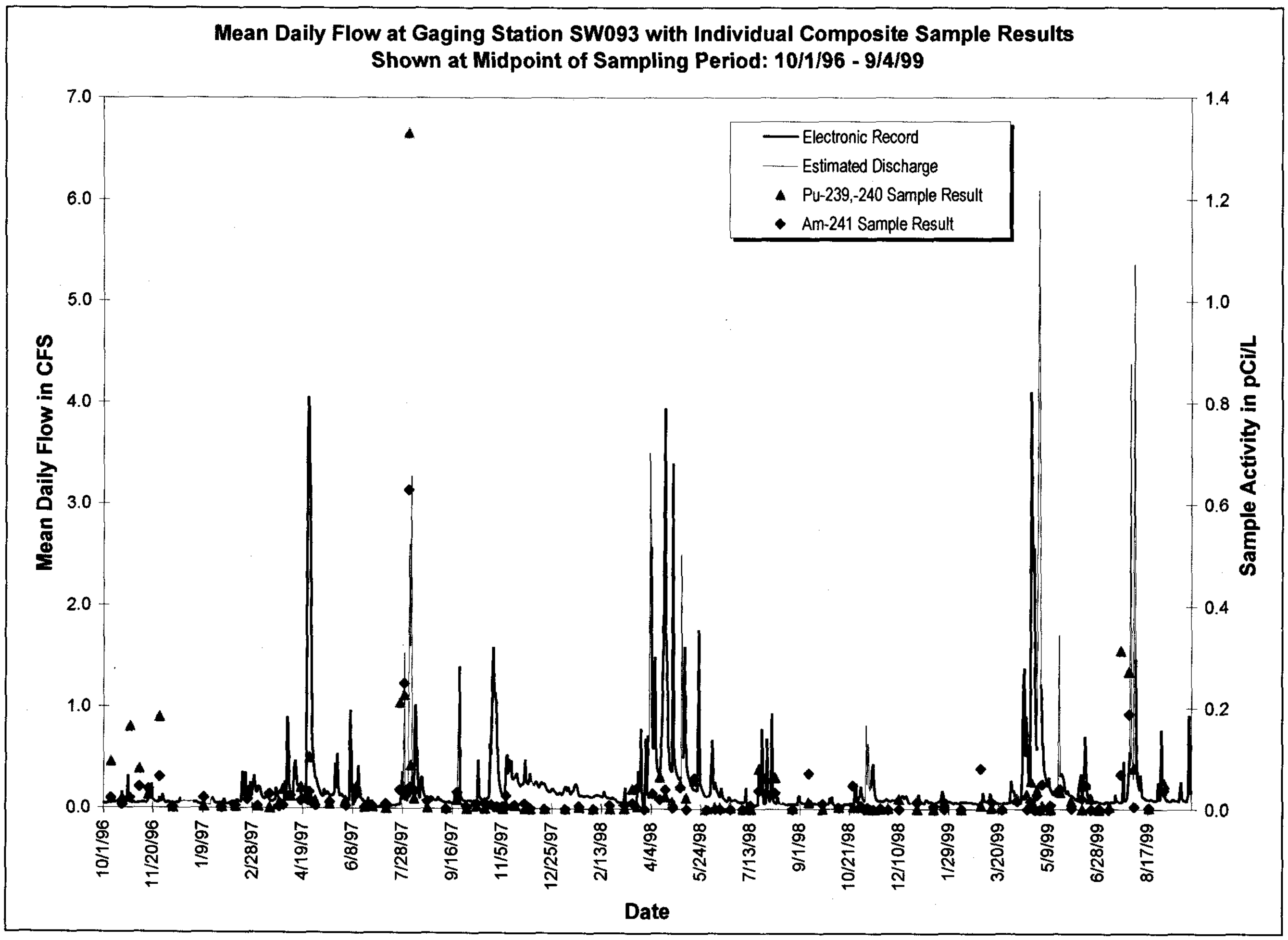

Figure 3-4. Gaging Station SW093 Hydrograph with Individual Sample Results.

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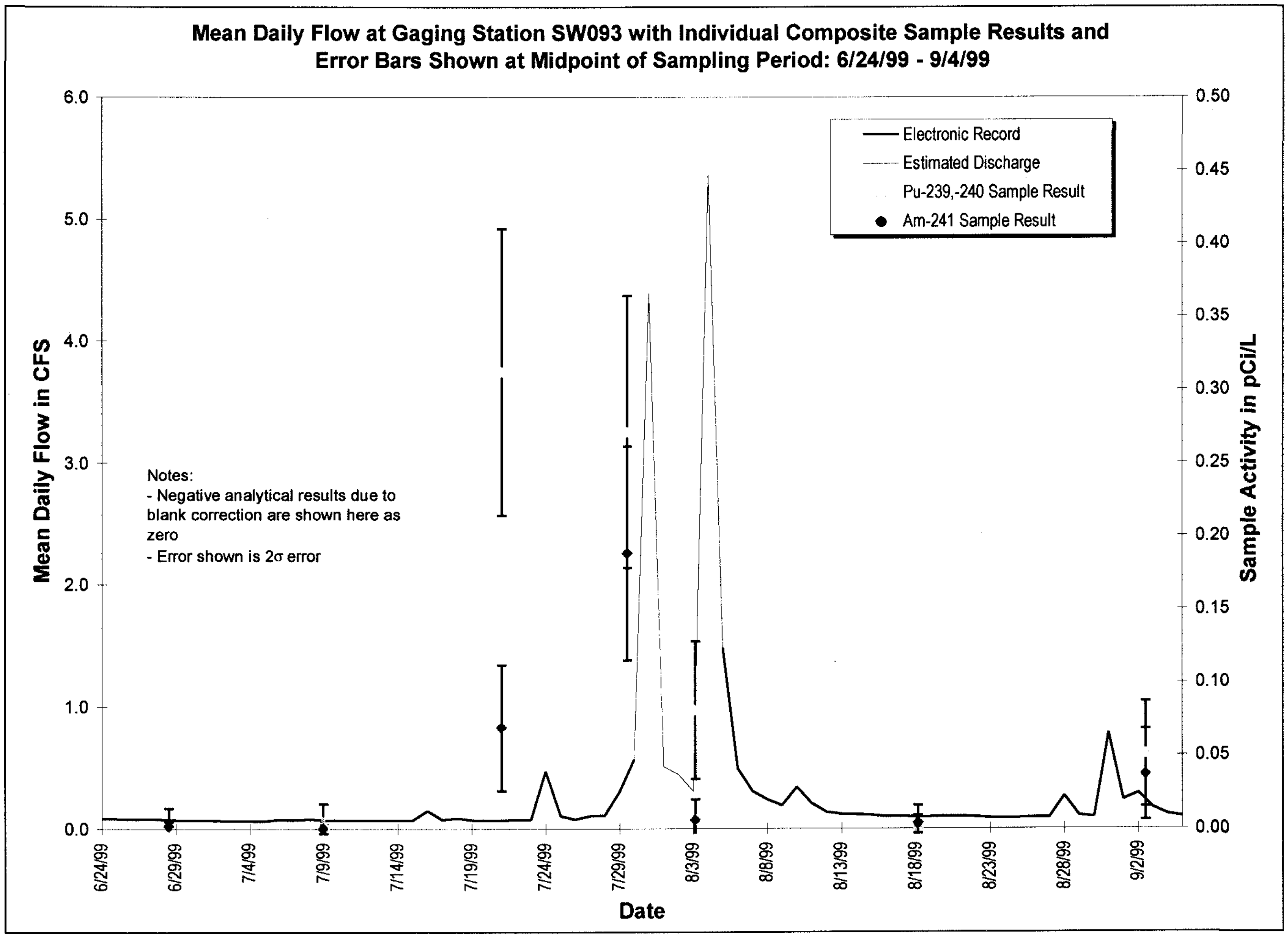

Figure 3-5. Gaging Station SW093 Hydrograph with Individual Sample Results and Error Bars: June 24 Through September 4, 1999.

All water monitored at SW093 during this period flowed to Pond A-3, was batch discharged to Pond A-4, and was eventually direct discharged to lower Walnut Creek. Pre-discharge samples of the water in Pond A-4 indicated acceptable water quality for all discharges. Analytical results from composite samples collected at gaging station GS11 at the Pond A-4 outfall during the August 27 – September 7, 1999 discharge were well below the RFCA standard (Figure 3-6). All water discharged from Pond A-4 to Walnut Creek subsequently flowed through RFCA POC GS03. Analytical results from composite samples collected at GS03 during this discharge were well below the RFCA standard (Figure 3-7).

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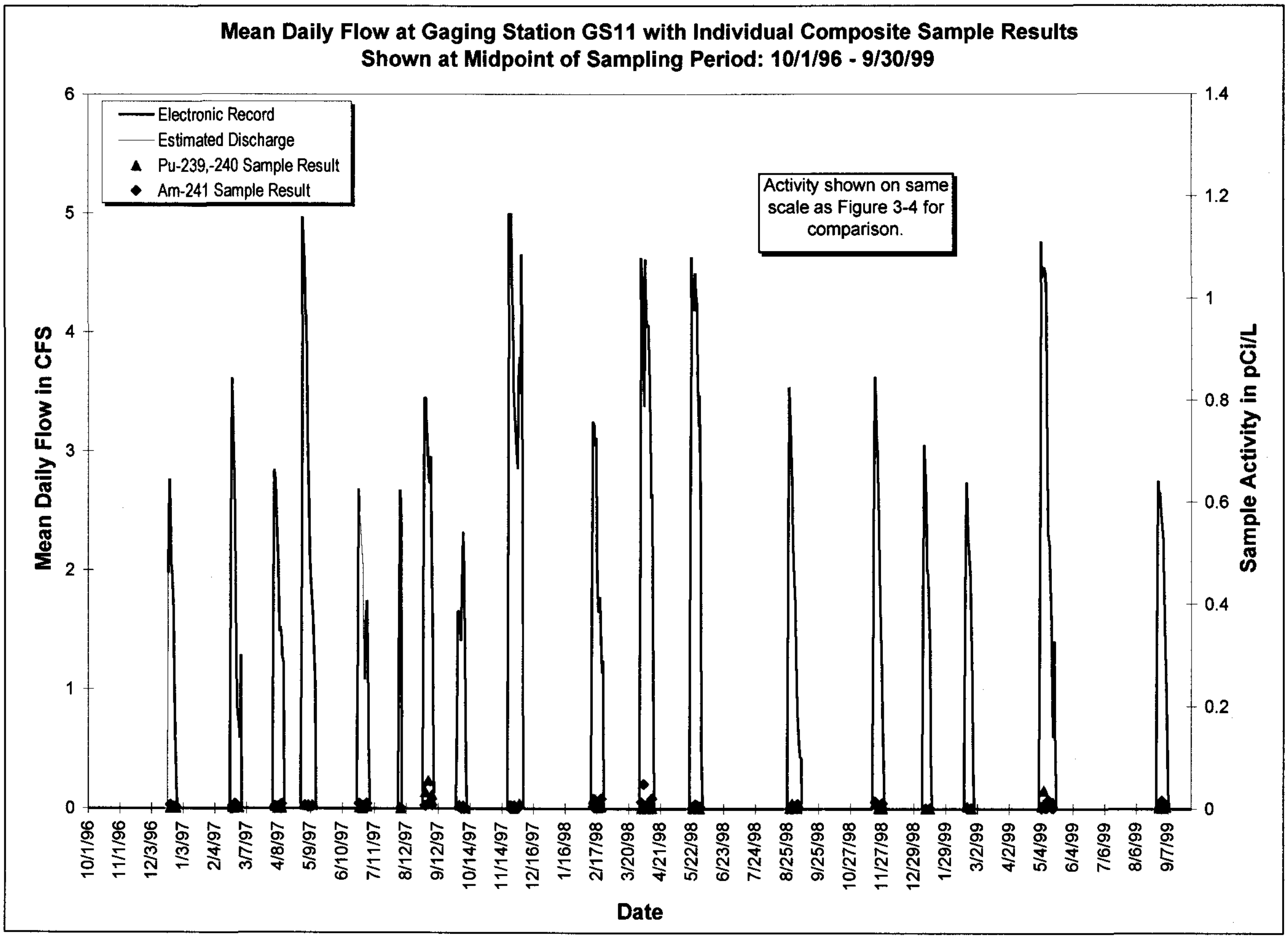

Figure 3-6. Gaging Station GS11 Hydrograph with Individual Sample Results.

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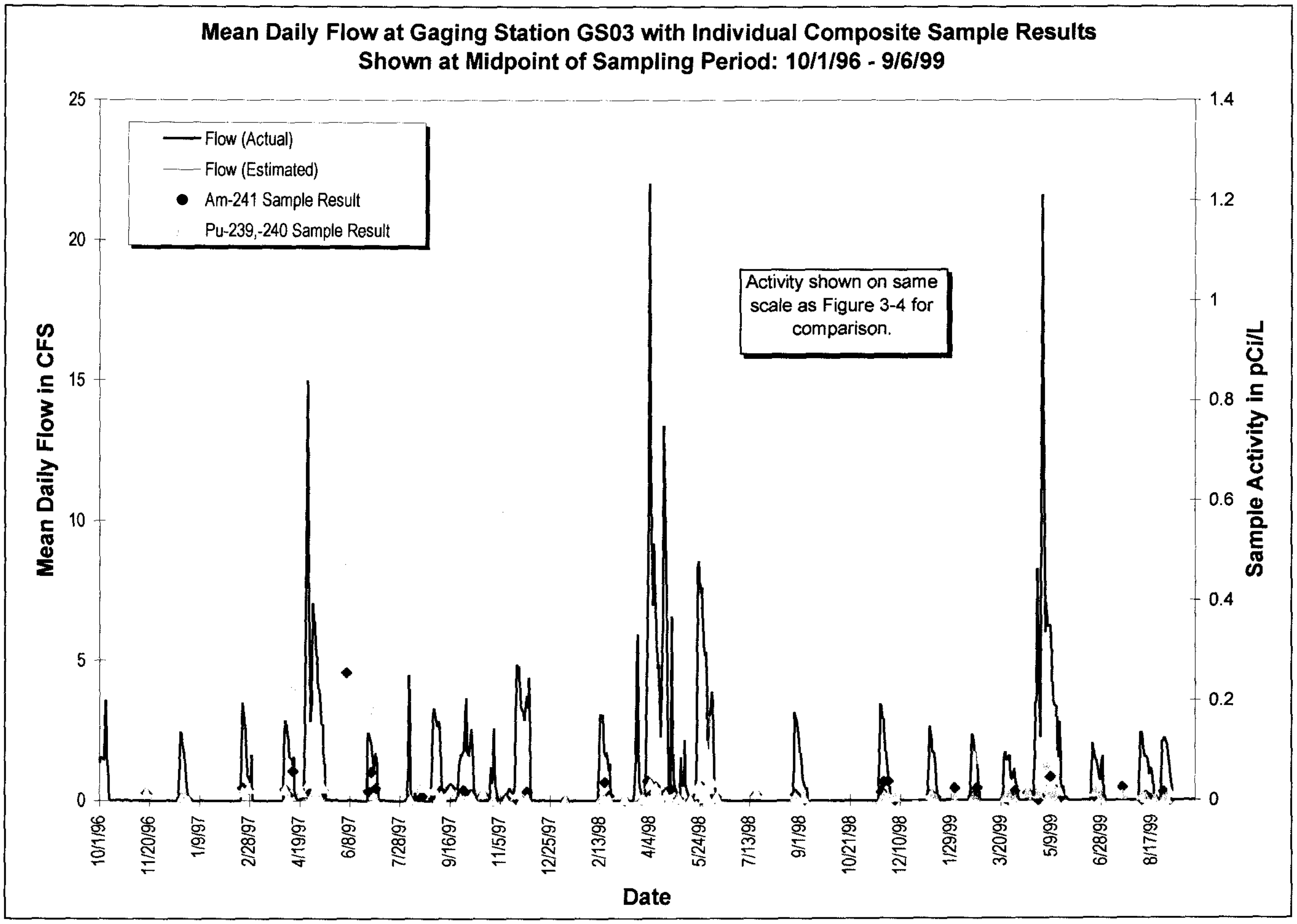

Figure 3-7. Gaging Station GS03 Hydrograph with Individual Sample Results.

4. DATA SUMMARY AND ANALYSIS FOR SW093

4.1. DATA QUALITY ASSESSMENT

This section provides the results of the data quality assessment that was conducted in accordance with the Evaluation of Data for Usability in Final Reports (RMRS Procedure, RF/RMRS-98-200 [RMRS, 1998b]). This procedure establishes the guidelines for evaluating analytical data with respect to precision, accuracy, representativeness, completeness, and comparability (PARCC). Isotopic determinations by alpha spectroscopy were quantitatively evaluated for this data quality assessment. This data quality assessment ensures that data used in making management decisions for remedial actions is of adequate quality to support the decisions.

4.1.1. Analytical Data Verification and Validation

Verification ensures that data produced and used by the project are documented and traceable per quality requirements. Generally, verification consists of reviewing the data to determine whether:

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- Chain-of-Custody was intact from initial sampling through transport and final analysis;
- Preservation and hold-times were within tolerance;
- Selected samples underwent analysis at certified labs; and
- Data format and content is clearly presented relative to the goals of the project.

In addition to the criteria noted above, verification of the data also included additional checks sometimes acknowledged as within the "validation" category, depending on the type of analysis:

- Surrogate recovery;
- MS/MSD recovery;
- Calibrations;
- Blanks;
- Sample preparations; and
- Other quality control.

In order to provide an integrated evaluation of the data quality, results of the verification are collectively discussed with validation below.

Validation consists of a technical review of the data, or a portion of the data, so that any limitations of the data relative to project goals are identified, and the associated data are qualified accordingly. All surface water isotopic data are either verified or validated, based on criteria determined by the K-H Analytical Services Division (ASD), or the special request of the customer. Approximately 75% of all isotopic data are verified and the remaining 25% are validated. Satisfactory validation at this frequency indicates that the subcontracted labs are operating competently relative to industry-wide standards, and more specifically, that sample custody and analytical procedures are implemented under defined quality controls. Validation is typically determined randomly for each subcontracted laboratory, based on the specific analysis suite. This random determination may or may not routinely include POE or POC locations.

Validation by an independent third party was performed on 100% of the isotopic alpha spectroscopy data for the five SW093 surface water samples submitted during the time period covered in this report (6/24 through 8/3/99). In addition, all data packages were reviewed by an ASD staff radiochemist prior to submission for validation. The data packages were all found to be compliant with quality requirements and no significant qualifications to the data were made. Original verification and validation (V&V) packages for the project are managed and filed by the K-H ASD, Building 881. The data were also evaluated with respect to the project quality requirements described in the next section.

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4.1.2. PARCC Evaluation

Precision

Precision is the measure of the reproducibility of analytical results. For radiological analyses, precision is expressed quantitatively by the Duplicate Error Ratio (DER) between real and duplicate sample results and is expressed by the following equation:

$$DER = \left[\frac{C_1 - C_2}{\sqrt{\left(TPU_{c1}^2 + TPU_{c2}^2\right)}} \right] 100$$

C_1 = first sample result (in terms of concentration)

C_2 = duplicate sample result (in terms of concentration)

TPU = total propagated uncertainty

The DER ratio was not calculated, since duplicate samples were not collected for any of the five composite samples (99D8397-002, 99D8970-001, 99D9028-005, 99D9321-002, and 99D9386-005) used to calculate the 30-day moving averages for plutonium during the period of July 25 through August 3, 1999 at SW093. Therefore, overall precision for this sampling period cannot be determined. However, laboratory precision was acceptable based on the results of the equivalency test statistic (DER calculation used for laboratory duplicate samples). The equivalency test statistics for the laboratory duplicate samples associated with the five referenced samples ranged from 0.025 to 0.974 well below the equivalency test criterion of 1.5.

Accuracy

Accuracy is evaluated by comparing the required analytical method and detection limit with the actual method used and its detection limit for each analyte. Table 4-1 provides a comparison between required detection limits and actual detection limits.

Table 4-1. Comparison of Detection Limits – Alpha Spectroscopy.

Analyte	Required Analytical Statement of Work	Required Detection Limit (pCi/L)	Actual Detection Limit (pCi/L)
Pu-239,-240	RC01B.3	0.03	0.019 – 0.022
Am-241	RC01B.3	0.03	0.019 – 0.027

As can be seen in Table 4-1, the actual detection limit was lower than the required detection limit for plutonium and americium. Therefore, accuracy from alpha-spectroscopy detection limits was adequate for all sample analyses for decision-making purposes. Percent recoveries on the laboratory control samples ranged from 80.3% to 124%, within their acceptable range of 75% to 125%. In addition, quality control tracer yields for Am-243 and Pu-242 ranged from 44.3% to 98.59%, within their acceptable tolerance range of 20% to 110%.

Representativeness

Typically the discussion of representativeness is limited to an evaluation of whether analytical results for field samples are truly representative of environmental concentrations or whether they may have been influenced by the introduction of contamination during collection and handling. This is assessed by evaluating the results of various blanks, specifically equipment rinseates. This aspect of representativeness was not evaluated, as equipment rinseate samples were not collected during the sampling period 6/24/99 through 8/3/99 at SW093. Sample representativeness was insured by the use of standard equipment decontamination procedures for reusable sampling equipment (e.g., sample bottles [carboys]) which are used to collect the composite surface-water samples. Other aspects of representativeness such as the number of samples and spatial distribution were determined prior to sample collection and are addressed in the *Integrated Monitoring Plan* (Kaiser-Hill, 1998) and the *Automated Surface-Water Monitoring Program Work Plan* (RMRS, 1999).

Completeness

Completeness is a quantitative measure of data quality expressed as the percentage of valid or acceptable data obtained from a measurement system. All composite surface water samples specified in the Work Plan (RMRS, 1999) for the period 6/24/99 through 8/3/99 were collected. As such, completeness is assumed to be 100%, which exceeds the goal of 90%. However, one data gap was identified during the above referenced sampling period at SW093. The sample bottle (carboy) for the composite sample dated 7/26/99 filled prior to being replaced. Due to unanticipated large runoff volumes, the 7/26/99 composite sample bottle filled at 1702 on Saturday 7/31/99. Approximately 1 inch of precipitation on 7/31/99 resulted in peak flow rates of 65 cubic feet per second and corresponding extremely high sample-collection frequencies at SW093. Consequently, 68 of the 110 total flow paced samples for the 7/26/99 composite sample were collected during the period 1520 through 1702 on 7/31/99. Site personnel were alerted to the full bottle condition during off-hours at home through the monitoring telemetry system. Site personnel collected the full composite bottle and started a new composite sample on Sunday 8/1/99 at 1136. Consequently, surface water runoff during the period 1702 on Saturday 7/31/99 to 1136 on Sunday 8/1/99 was not sampled at SW093.

Comparability

Analytical methods and sampling techniques remained consistent for each analyte group over the sampling period. All laboratory analyses for uranium, plutonium, and americium in water were performed in accordance with the K-H ASD contract specifications for Isotopic Determinations by Alpha Spectroscopy protocols (Module RC01B.3) and results are comparable to data produced by similar methods at other laboratories.

4.2. AUTOMATED SURFACE-WATER MONITORING DATA

4.2.1. Data Summary

All data and results used in this section, unless noted otherwise, were recorded by or were derived from samples collected by the Site's Automated Surface-Water Monitoring System established in the early 1990's. This section uses data from monitoring locations GS32, GS38, GS40, SW118, and SW093.[9] Table 4-2 gives the operation dates of these locations.

Table 4-2. Operation Dates for Selected Automated Monitoring locations.

Location	Dates of Operation
GS32	1/31/97 – present
GS38	1/28/98 – present
GS40	3/4/98 – present
SW118	9/11/91[a] – present
SW093	9/11/91[b] – present

[a] SW118 was established as a sampling location on 9/11/91; automated monitoring began on 12/12/95.
[b] SW093 was established as a sampling location on 9/11/91; automated monitoring began on 3/12/94.

The following assumptions were used for data use in the following sections:

- When a negative analytical sample result is returned from the laboratories due to blank correction (for radionuclides), then a value of 0.0 (pCi/L or pCi/g) is used for calculation purposes.

- Until analytical data are validated, the data must be considered *preliminary and subject to revision*. Data that were rejected through the validation process were not used in this report.

- Real and field duplicate results are averaged when they originated from the same sampling event.

- Consideration of analytical error is not included in any of the data analysis. The results are used directly in the evaluations. The reader should note that error is associated with the analytical data, especially for the typically low levels of radionuclides measured in Site surface waters.

- Consideration of flow-measurement error is not included in any of the data analysis. The flow measurements are used directly in the evaluations. Flow measurement error for GS38, GS40, SW118, and SW093 is estimated to be in the 5% – 15% range. Error associated with the flow *estimations* for GS32 is unknown but may be as high as 50%.

- At locations that employ continuous flow-paced sampling, there may be periods with no analytical result for radionuclides, due to either a failed laboratory analysis or an insufficient sample quantity for analysis. In this case, the volume-weighted average for the corresponding water year is used as an estimate to allow for total load estimation.

- When the sample Total Suspended Solids (TSS) result was an 'undetect', half of the detection limit was used (typically half of 5 mg/L).

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[9] Although GS38 and GS40 are not tributary to SW093, flow data from these locations was used to estimate flow characteristics at GS32 (flow is not measured at GS32 under the current monitoring equipment configuration).

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Actinide Activities

Summary Analysis for SW093

Table 4-3 shows that long-term arithmetic average activities[10] at SW093 are close to the current RFCA Action Level of 0.15 pCi/L for plutonium and americium. Furthermore, the sample results show a range of four orders of magnitude.

Table 4-3. Summary Statistics for All Samples from SW093: March 14, 1991 to Present.

Sampling Location	Number of Samples	Pu-239,-240		Am-241	
		Arithmetic Average Activity (pCi/L)	Maximum Sample Result (pCi/L)	Arithmetic Average Activity (pCi/L)	Maximum Sample Result (pCi/L)
SW093	137	0.135	5.3	0.071	1.621

Includes all data that has been received by the Site as of 10/8/99.

Table 4-4 shows that volume-weighted average activities at SW093 under the more recent RFCA monitoring protocols are significantly lower than the current RFCA Action Level of 0.15 pCi/L for plutonium and americium. Although the *30-day* volume-weighted average activity has exceeded the reporting threshold for short periods twice in the last three years, the overall volume-weighted activities for the entire period of RFCA monitoring (10/1/96 – present; Table 4-4) and for individual water years (Figure 4-1) are significantly below the reporting threshold. In addition, maximum sample results during RFCA monitoring are roughly 20% of those measured with storm-event sampling. This is likely the result of the use of continuous flow-paced sampling which collects samples over all flow conditions.[11]

Figure 4-1 shows the average annual activities at SW093 for WY93 - WY99.[12] For WY93 - WY96, arithmetic averages of individual storm-event sample results are plotted. However, due to the continuous flow-paced sampling protocols currently in place under RFCA, the more representative volume-weighted average activities are shown for WY97-WY99. The reader should note that although elevated 30-day averages occurred in recent years, the volume-weighted average for these years is comparable to the activities for other years. This comparability suggests that actinides have been available for transport to SW093 for some time and that the recent elevated measurements at SW093 may be the result of legacy contamination and not current operations.

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[10] This arithmetic average includes all sample results regardless of sampling protocol. No distinction is made between unknown, grab, flow-paced storm-event, and continuous flow-paced sampling protocols. The arithmetic average is calculated to provide a reference for 'typical' activities measured at SW093.

[11] Storm-event sampling focuses on sampling higher flow-rate runoff events (with the corresponding increased transport of particulate matter). Continuous flow-paced sampling also includes sampling during low-flow baseflow periods (with the corresponding decreased transport of particulate matter).

[12] Data for WY99 are incomplete. Results from the final two composite samples have not been received by the Site.

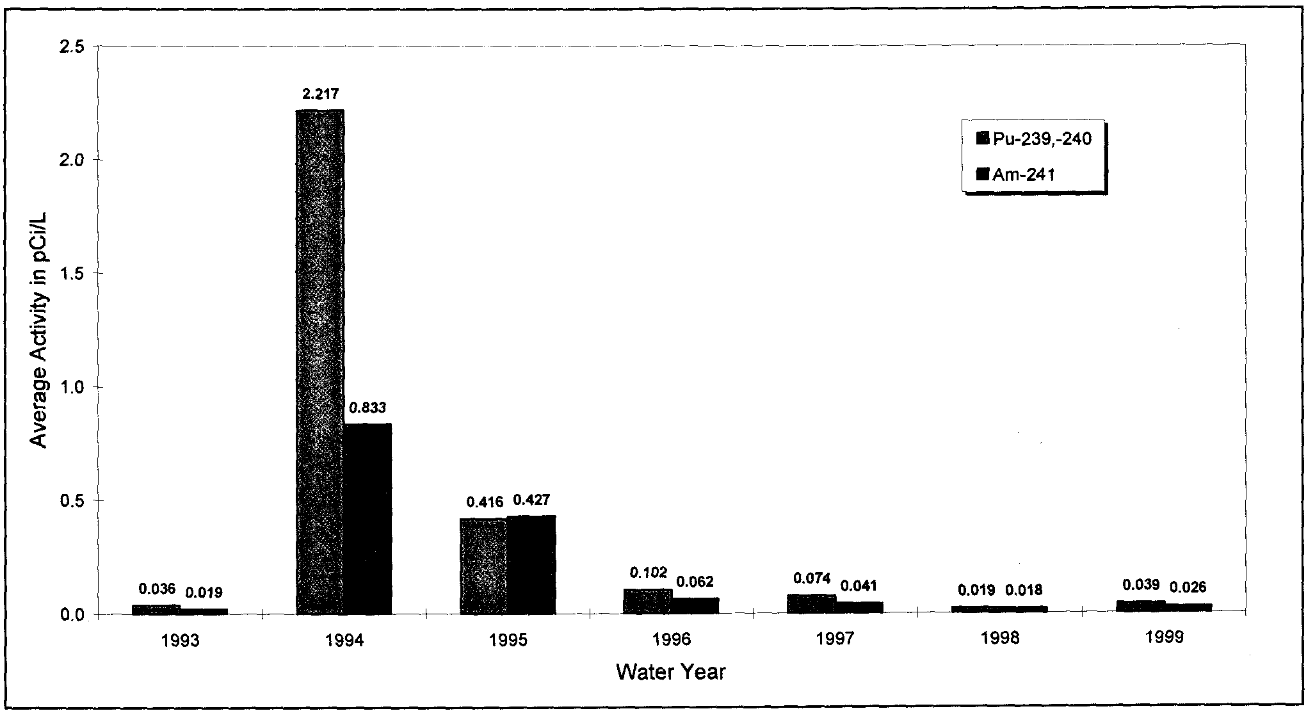
The significantly higher calculated loads for WY94-95 is likely the result of the preferential sampling of large runoff events. Storm-event sampling is biased toward the collection of samples during larger runoff events with higher activities for the following reasons:

- Samples are targeted to be collected on the rising limb of a runoff hydrograph, with the emphasis on larger runoff events, and
- Larger runoff events tend to have higher activities due to increased particulate transport.[13]

Table 4-4. Summary Statistics for RFCA Samples from SW093: October 1, 1996 to Present.

Sampling Location	Number of Samples	Pu-239,-240		Am-241	
		Volume-Weighted Average Activity (pCi/L)	Maximum Sample Result (pCi/L)	Volume-Weighted Average Activity (pCi/L)	Maximum Sample Result (pCi/L)
SW093	108	0.04	1.33	0.026	0.628

Includes all data that have been received from analytical labs as of 10/8/99.



Includes all data that have been received as of 10/8/99. WY99 activity calculated through 9/3/99.

Figure 4-1. Average Plutonium and Americium Activities at SW093: WY93 - WY99.

[13] Actinides transported by surface water are generally associated with particulate matter. During larger runoff events, increased flow rates and precipitation intensity will suspend and mobilize larger quantities of particulate matter, and the associated actinides. See Section 6 for detail.

Nonparametric statistical methods to estimate quantiles[14] were applied to data sets of both individual composite-sample results and 30-day average values for plutonium at SW093. Figure 4-2 shows that the individual sample results do not have a normal distribution. In addition, nonparametric statistics suggest that approximately 7% of individual results could be expected to be greater than 0.15 pCi/L based on the existing data.

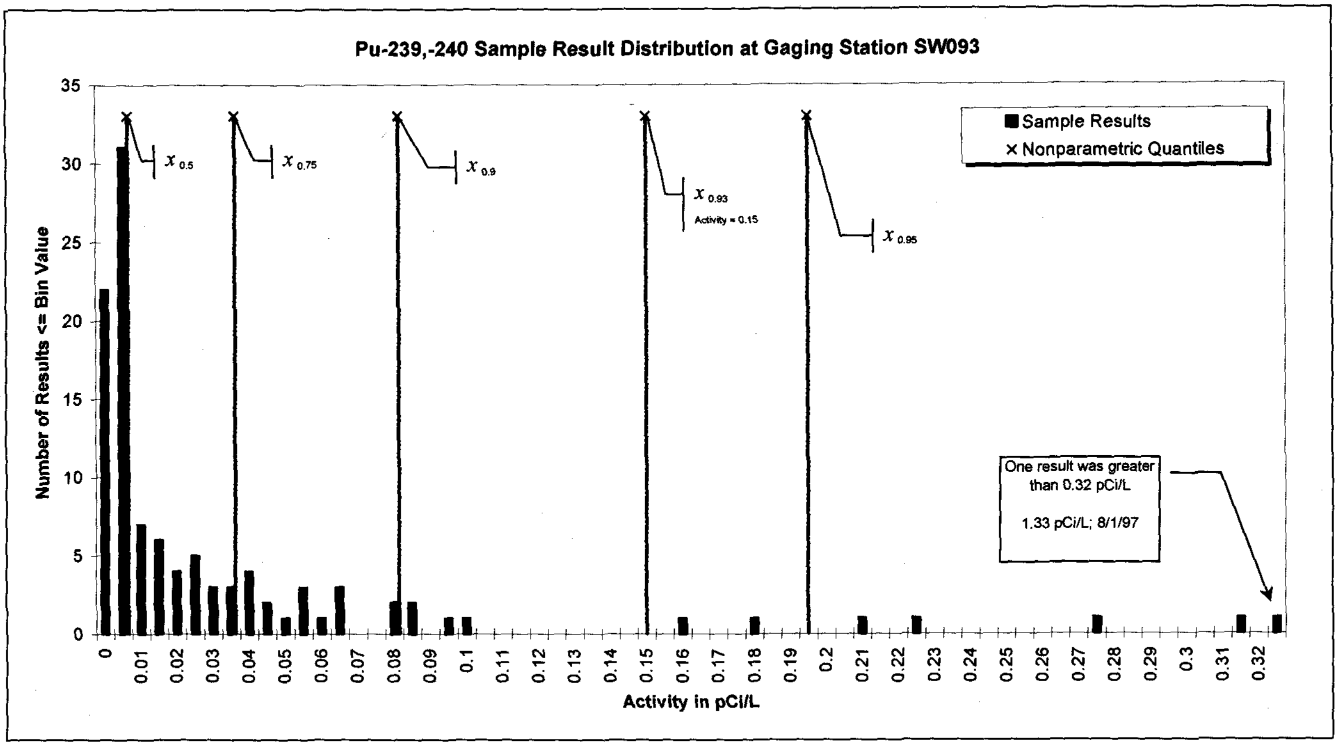


Figure 4-2. Histogram and Nonparametric Quantiles for Composite Sample Plutonium Results from SW093: WY97 – WY99.

Figure 4-3 shows that the 30-day average values also do not have a normal distribution. Nonparametric methods suggest that approximately 1% of 30-day average values could be expected to exceed 0.15 pCi/L.

[14] Nonparametric methods are distribution-free, and do not depend for their validity upon the data being drawn from a specific distribution, such as the normal or log-normal. The pth quantile, x_p (where $0 < p < 1$), is the value such that the probability is p that a unit in the population will have an observed value less than or equal to x_p, and the probability is $1 - p$ that a units value will be larger than x_p.

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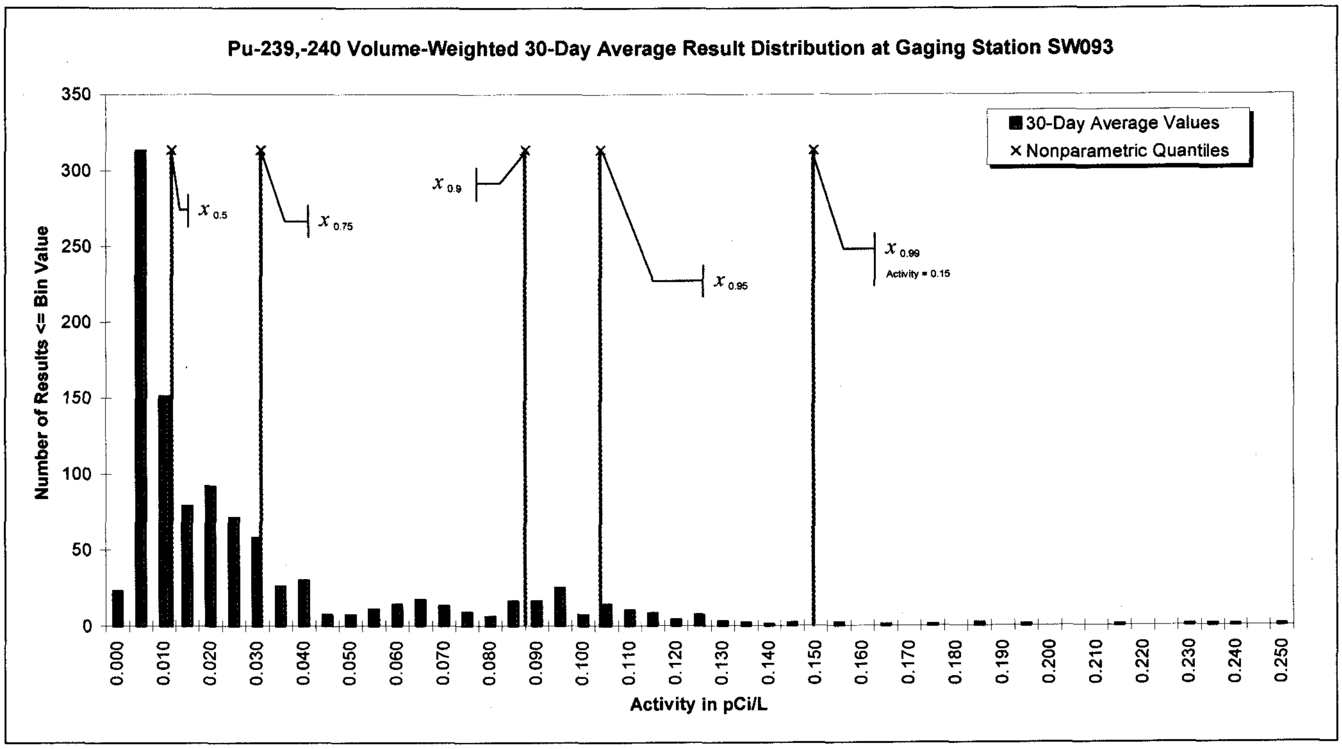

Figure 4-3. Histogram and Nonparametric Quantiles for 30-Day Average Plutonium Values from SW093: WY97 – WY99.

Tributary Surface-Water Sampling and Monitoring Locations

Analytical results from 21 historical surface-water sampling locations tributary to SW093 were compiled from the Rocky Flats Soils and Water Database (RFSWD). All sample dates to the present were compiled; however, results rejected by validation were excluded. The sorted data were filtered to limit the results to real field samples[15]. Field and laboratory QC data were not examined. The data were summarized to produce location-specific averages and maxima. The maximum individual sample results by location were mapped to identify portions of the SW093 drainage basin associated with higher plutonium activities in surface-water runoff. These maximum plutonium activities are presented in Table 4-5 and mapped in Figure 4-4.

Maximum surface-water sample plutonium activities observed within the SW093 drainage basin show a range of three orders of magnitude (0.001 to 4.0 pCi/L). The results indicate no clear discrete source area. However, several of the higher results were collected in the B771/B774 area (SW084 and SW086). Two locations upstream from SW118 also had high maximum results (4.0, 0.3 pCi/L plutonium). Both results are from 1990 samples, and recent sampling at SW118 shows low activities from the sub-drainage that includes these locations.

[15] When a duplicate was analyzed for the same sample event, the two results were averaged to produce the result for the sampling event.

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Table 4-5. Maximum Plutonium Activity for Sample Results from Surface-Water Sampling Locations Tributary to SW093.

Location Code	Maximum Pu Activity (pCi/L)
SED05395	0.006
SED05495	0.002
SED05995	0.003
SED06295	0.004
SED06595	0.025
SED06695	0.040
SED06895	0.001
SED07095	0.043
SED07195	0.190
SED07395	0.380
SED07495	0.011
SED07895	2.9
SED08195	0.003
SW018	0.040
SW043	0.030
SW084	0.440
SW086	0.542
SW102	0.070
SW116	0.300
SW117	4.0
SW124	0.012

Note: Location codes starting with SED indicate locations established as sediment sampling locations; however, surface-water samples were collected at these locations.

Starting in WY98, two upstream automated-monitoring locations, GS32 and SW118 (Figure 3-2), have been operating in response to elevated plutonium measurements at SW093 during WY97.[16] These stations were installed or upgraded to monitor sub-drainages that are tributary to SW093. Sample results from these locations can be used to measure plutonium and americium loads from the respective sub-drainages in an attempt to identify any discrete source areas. Summary statistics for sample results from these locations are shown in Table 4-6. The activities for GS32 are arithmetic averages since sampling at this location occurs only during selected storm events. Continuous flow-paced sampling is employed for SW093 and SW118, and volume-weighted average activities are given in Table 4-6. These data show that the average activities at GS32 are 50-100 times greater than those for SW093. This comparison suggests that the GS32 sub-drainage may be a significant contributor to the activities at SW093 (the loading analysis discussed later in Section 4.2.2 supports this hypothesis).

[16] GS32 was initially installed as a Performance Monitoring location in support of the B779 D&D (Pu and Am have always been analyzed at GS32). SW118 was initially installed as a Buffer Zone Hydrologic Monitoring location to measure flow only at the request of DOE. SW118 was upgraded to collect continuous flow-paced samples for Pu and Am on 11/30/97.

Table 4-6. Summary Statistics for Samples from SW093 and Monitoring Locations Tributary to SW093: WY97 to Present.

Sampling Location	Number of Samples	Pu-239,-240 Average Activity (pCi/L)	Pu-239,-240 Maximum Sample Result (pCi/L)	Am-241 Average Activity (pCi/L)	Am-241 Maximum Sample Result (pCi/L)
SW093	73	0.028	0.312	0.021	0.188
GS32	17	2.43	11.5	1.22	3.96
SW118	27	0.005	0.045	0.005	0.027

Includes all data that have been received as of 10/8/99.

Water-Quality Trends and Correlations

Relationships between sample activities and corresponding field-data parameters can provide insight into the transport mechanisms associated with the movement of actinides in surface-water. It is generally accepted that the plutonium and americium move in surface-water associated with suspended particulate matter. Figure 4-5 shows an apparent trend between sample plutonium activity and TSS.

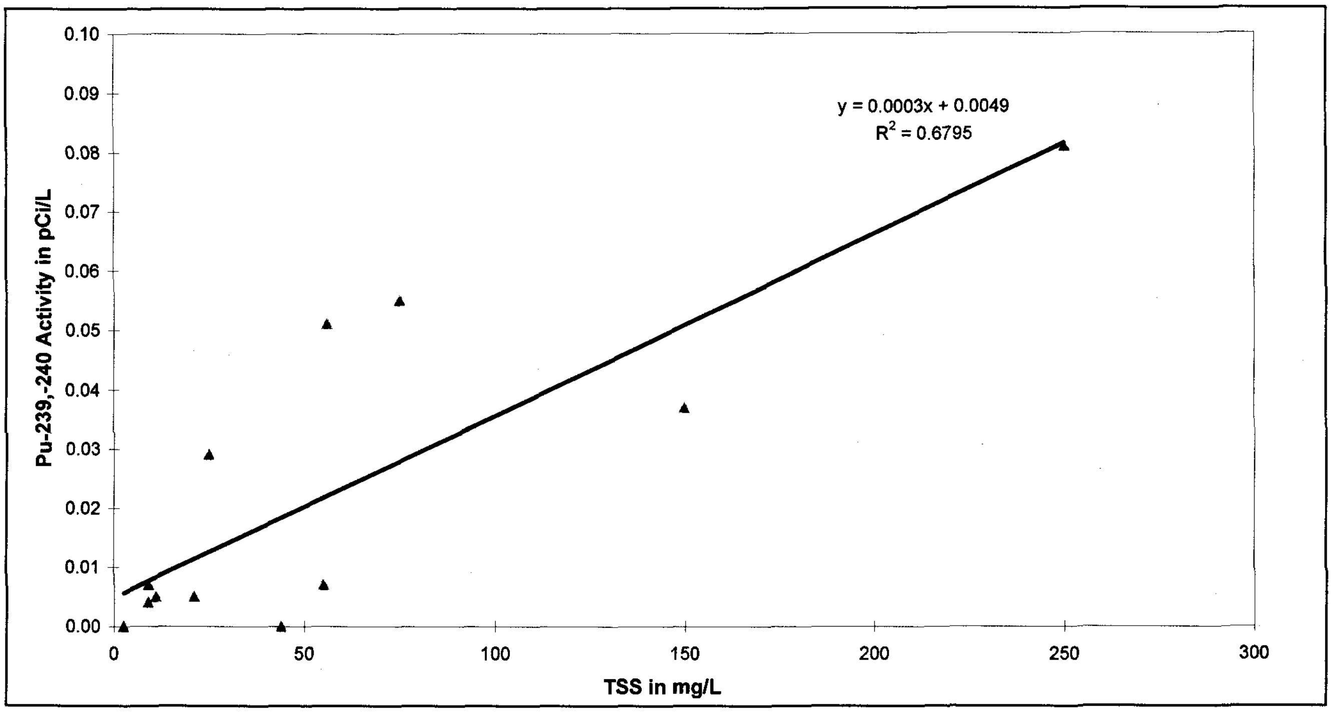

Figure 4-5. Variation of Plutonium with Total Suspended Solids at SW093: WY97 – Present.

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If suspension of TSS increases with the intensity of storm events[17], then a correlation should exist between sample TSS concentrations and sample period flow rates. Figure 4-6 shows an apparent trend for sample TSS concentration with both average and peak flow rates during the corresponding sample period.

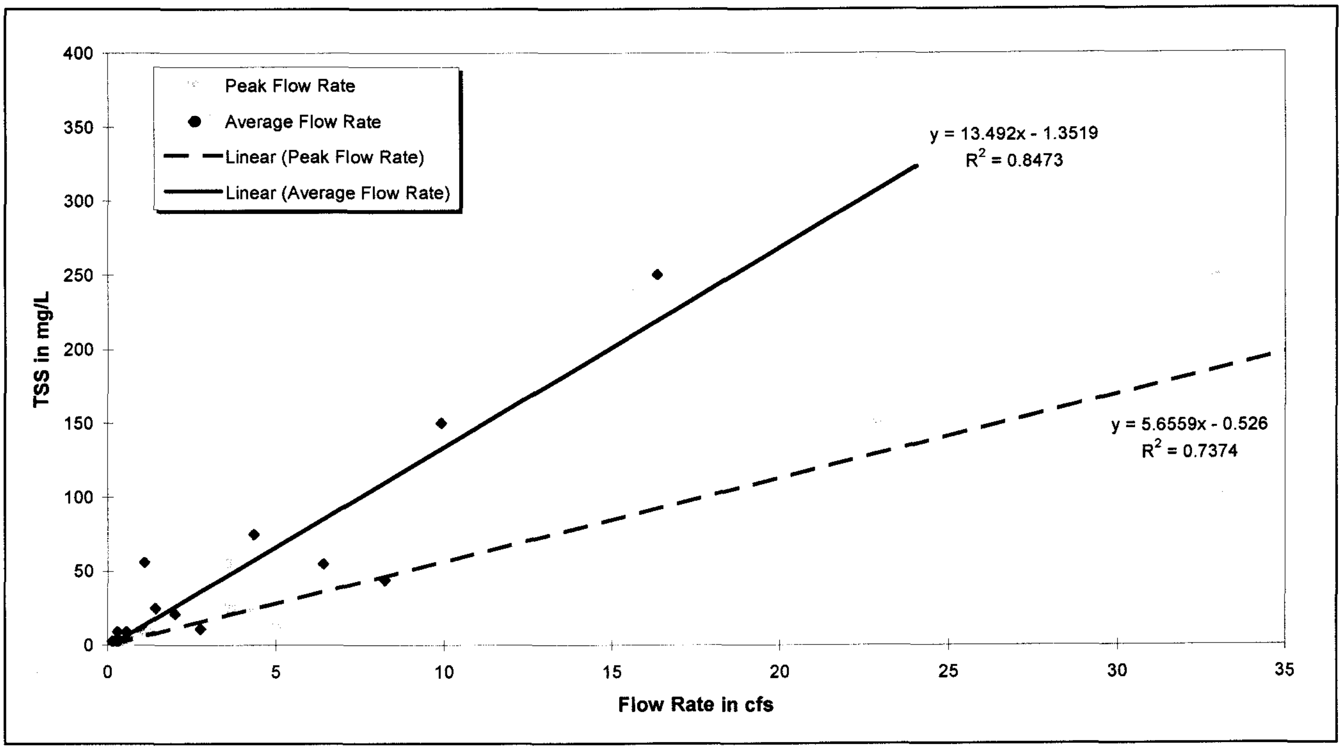

Figure 4-6. Variation of Total Suspended Solids with Average and Peak Flow Rate at SW093: WY97 – Present.

Based on the conclusions drawn from Figure 4-5 and Figure 4-6, it could be expected that a correlation may also exist between sample plutonium activity with both average and peak flow rates during the corresponding sample period. However, this is not the case as shown in Figure 4-7 and Figure 4-8. This may be explained by the following:

- The trends in Figure 4-5 and Figure 4-6 are not strong, and the combination of the two result in an even weaker correlation.
- The variability of precipitation over the SW093 drainage area (219 acres; approximately 1.2 x 0.5 miles) results in runoff at SW093 for similarly *sized* precipitation events originating from various sub-drainage areas depending on precipitation patterns. Consequently, two storms resulting in similar net runoff as measured at SW093 may actually contain very different proportions of runoff from the various sub-drainages. Assuming

[17] Higher intensity precipitation events are expected to result in higher TSS movement due to raindrop impact and increased overland flow velocities. Similarly, increased stream/ditch flow rates are expected to result in increased scour and sediment mobilization.

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that the SW093 drainage contains multiple sub-drainages with differing surface characteristics (disturbed soil, compacted soil, vegetated soil, pavement, etc.) and varying levels of contamination, then similar flow rates at SW093 could contain differing levels of both plutonium and TSS, depending on where runoff originated.

- Similarly, the variability of the size of individual precipitation events could cause runoff to originate from various sub-drainage areas depending on differing surface characteristics (disturbed soil, compacted soil, pavement, etc.) of the various sub-drainages. For example, a high-gradient sub-drainage with substantial impervious surface area could contribute runoff to SW093 for any storm exceeding 0.05 inches of precipitation. Conversely, a low-gradient sub-drainage with substantial pervious surface area may only contribute runoff to SW093 for any storm exceeding 1.0 inch of precipitation. Therefore, varying total precipitation accumulations, resulting in varying runoff origin (from contaminated and/or uncontaminated sub-drainages), could cause weak relationships between measured parameters at SW093.

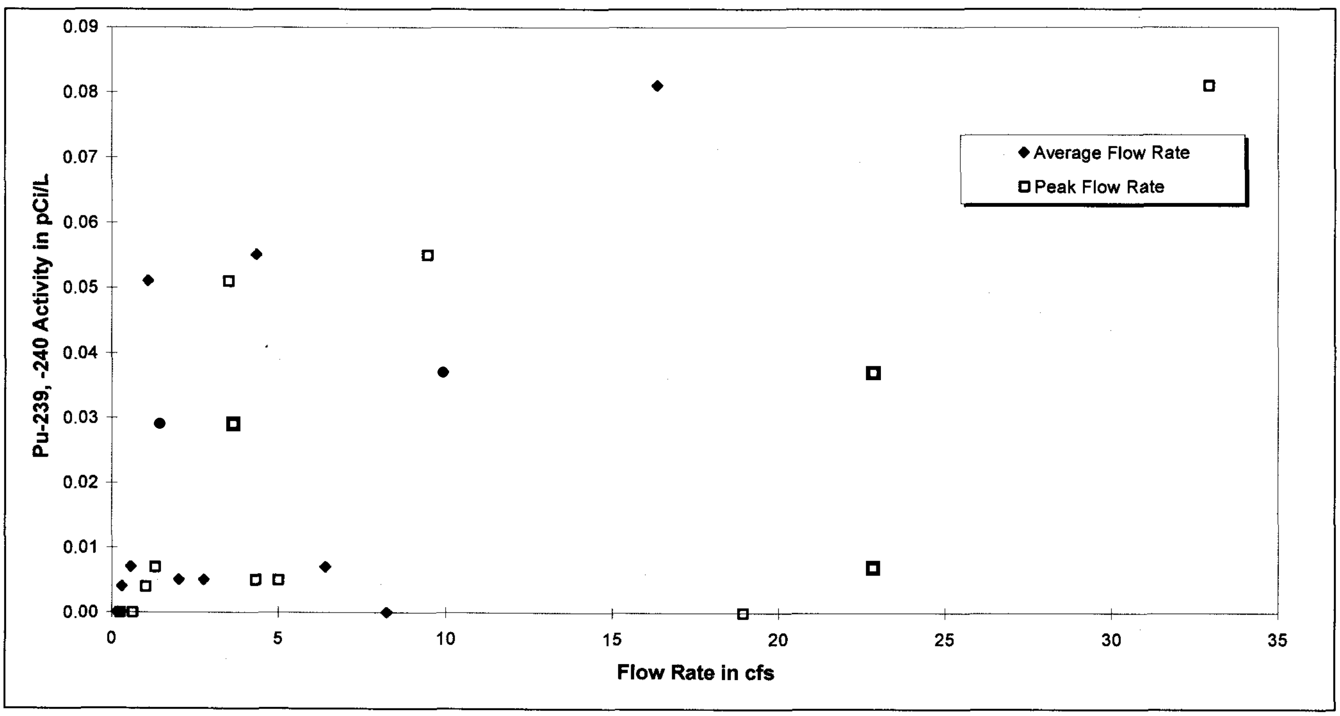

Figure 4-7. Variation of Plutonium with Average and Peak Flow Rate at SW093: WY97 – Present (Samples with TSS Results Only).

As stated previously, recent sample results from GS32 indicate that the GS32 sub-drainage is likely a major contributor to the activities measured at SW093. Additionally, Figure 4-9 shows that the plutonium activity and TSS concentration of samples from GS32 have increased over time, inferring that the D&D activities at B779 may be negatively influencing water quality at GS32, and subsequently at SW093. An increasing activity could indicate that new source areas have been exposed to surface-water runoff, while increasing TSS concentrations could indicate that D&D work may be mobilizing additional TSS. However, Figure 4-10 through Figure 4-12 show that neither of these postulated consequences has been observed.

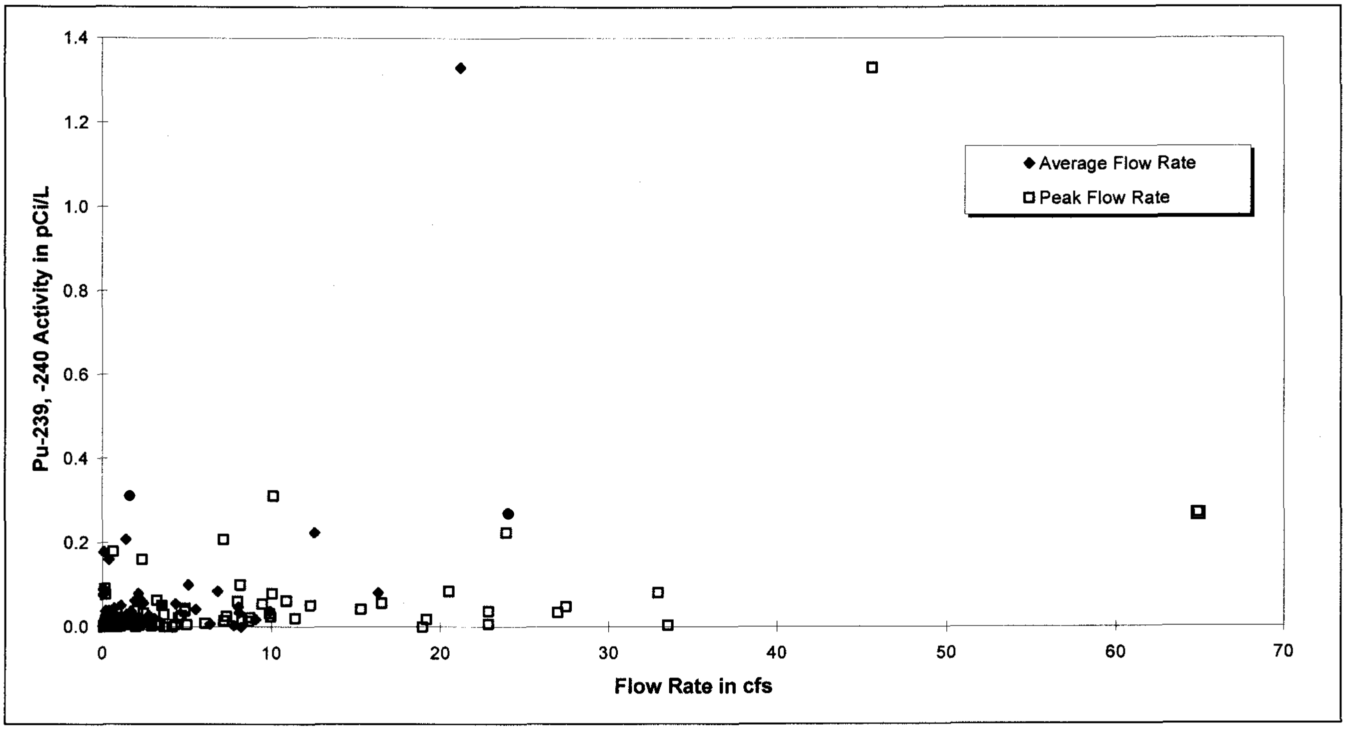

Figure 4-8. Variation of Plutonium with Average and Peak Flow Rate at SW093: WY97 – Present (All Samples).

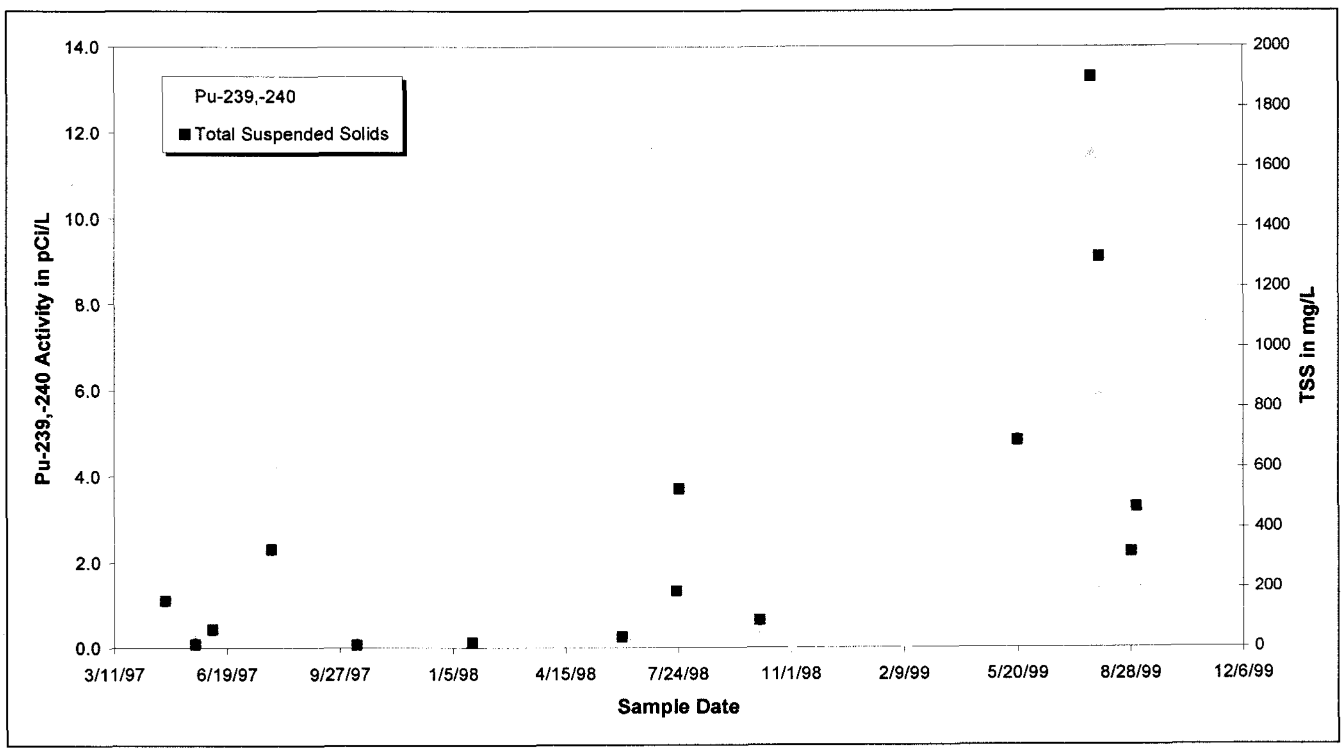

Figure 4-9. Variation of Total Plutonium Activity and Total Suspended Solids with Date at GS32: WY97 – Present.

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Figure 4-10 shows a strong correlation between plutonium activity and TSS concentration for samples collected at GS32. If new source areas were exposed in the GS32 sub-drainage due to D&D work, samples would be collected that would not fit this correlation, and would be plotted above (higher activity for a given TSS) the linear fit. In other words, samples with TSSs of higher specific activities[18] would be collected if new areas with higher soil/sediment Pu activities were exposed to surface-water runoff during D&D work. Similarly, Figure 4-11 shows that the specific activity of the TSS for samples collected at GS32 have not changed significantly over time. In fact, the most recent higher activity samples (Pu pCi/L) show measurably lower specific activities.

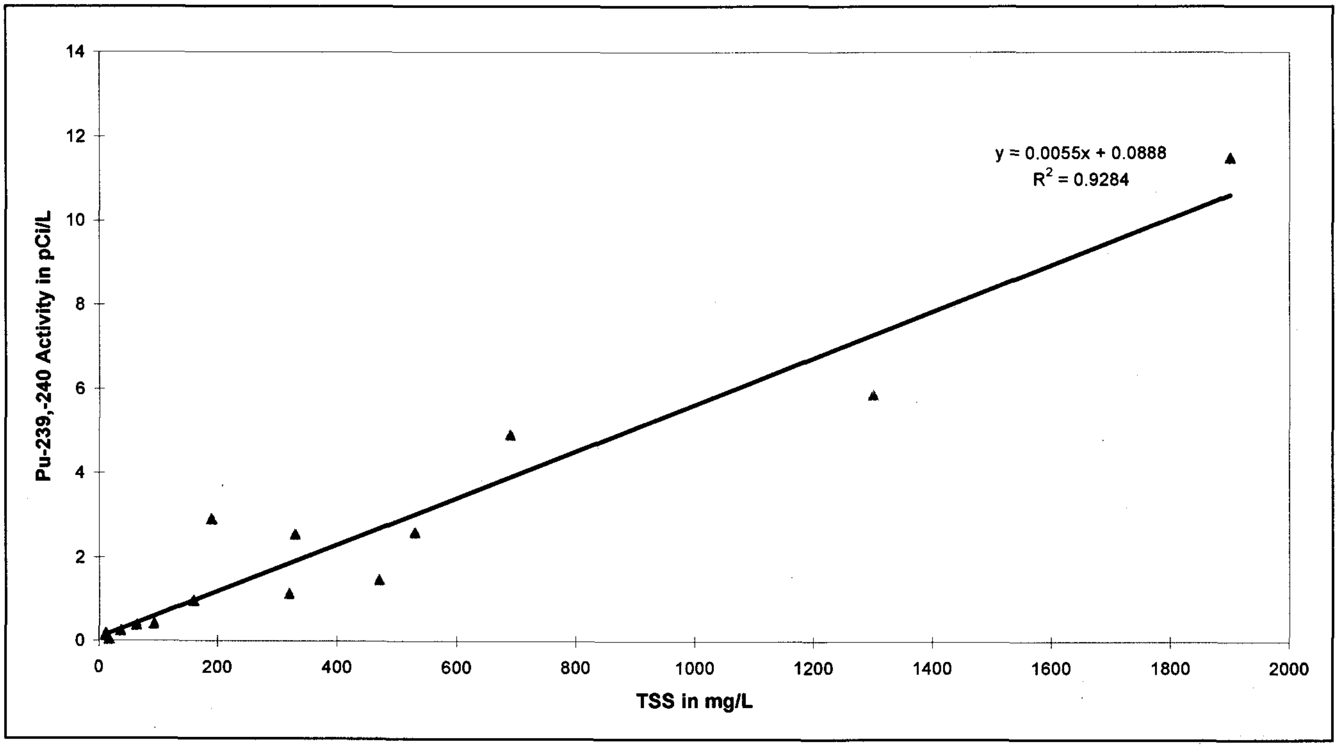

Figure 4-10. Variation of Plutonium with Total Suspended Solids at GS32: WY97 – Present.

Figure 4-12 shows that although the plutonium activities for samples collected at GS32 have increased over time, the peak flow rates at adjacent location GS40 for the sampled GS32 runoff events have also increased.[19] This indicates that the recent higher activities measured at GS32 are likely a result of intense runoff, and not a change in the GS32 sub-drainage due to D&D work.

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[18] The specific activity (Pu) of TSS in a sample is calculated by dividing the sample Pu activity (pCi/L) by the TSS concentration (mg/L) and converting to pCi/g. This assumes that there is very little *dissolved* Pu, and the vast majority of the measured Pu is associated with the TSS particulates. See Section 6 for detail.

[19] The GS40 sub-drainage is similar to that of GS32, and the peak flow rate at GS40 is assumed to be indicative of the runoff event intensity at GS32.

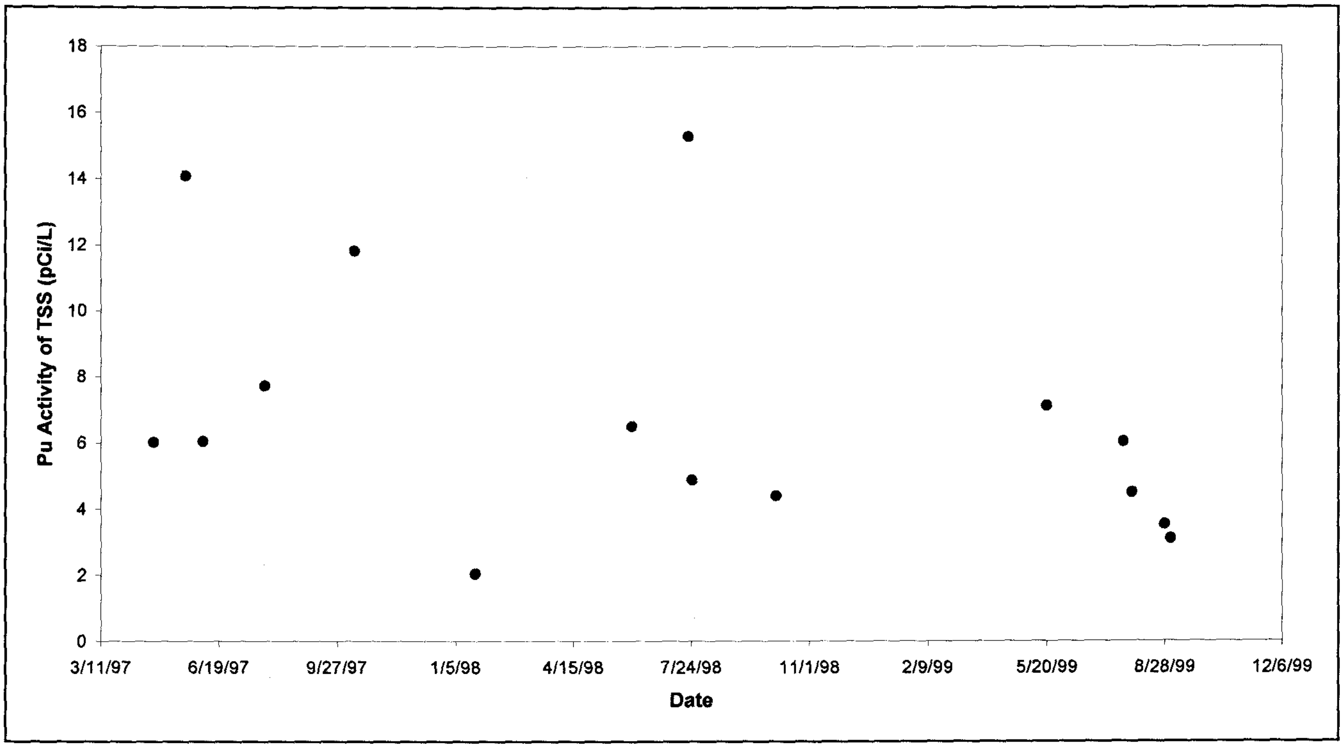
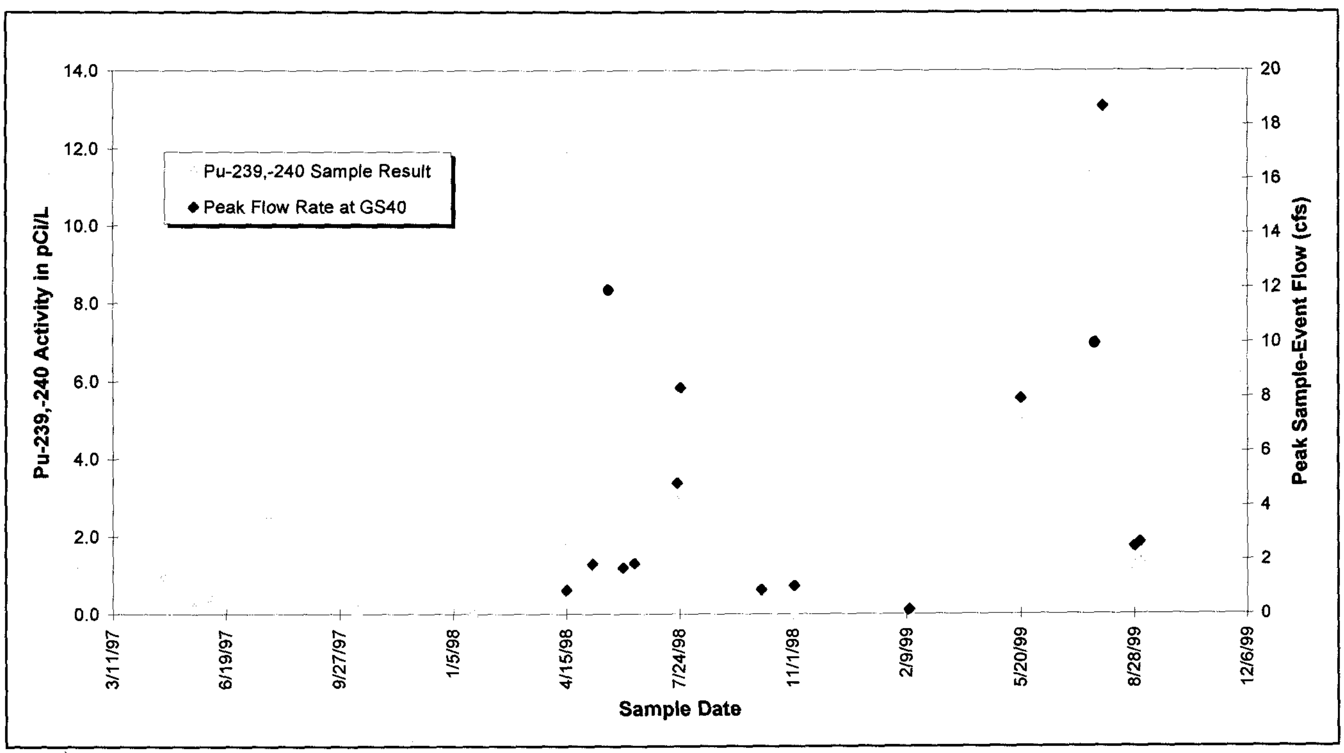


Figure 4-11. Variation of TSS Plutonium Activity with Sample Date at GS32: WY97 – Present.



Flow cannot be measured at GS32 with current equipment configurations. Flow rate at nearby GS40 is considered an indicator of flow rates at GS32. GS40 began operation in March 1998.

Figure 4-12. Variation of Plutonium and Peak Flow Rate with Sample Date at GS32: WY97 – Present.

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4.2.2. Loading Analysis

Annual SW093 Loads

Annual radionuclide loads for SW093 in micrograms are presented in Table 4-7 and plotted in Figure 4-13 to show long term loading to SW093. For WY93 - WY96, the arithmetic average activity of individual sample results is multiplied by the associated total annual discharge volume to get pCi, then converted to micrograms[20]. For WY97-WY99, the activity for each flow-paced composite sample is multiplied by the associated discharge volume to get pCi, then converted to micrograms and summed.[21] As stated previously, this suggests that actinides have been available for transport to SW093 for some time and that the recent elevated measurements at SW093 are likely the result of legacy contamination.

Table 4-7. Plutonium and Americium Loads at SW093: WY93 to Date.

Water Year	Pu-239,-240 Load in μg	Am-241 Load in μg
1993	46	0.5
1994	3965	32.5
1995	1436	32.2
1996	147	2.0
1997	176	2.1
1998	71	1.5
1999	120	1.7
WY98-WY99 Total	190.8	3.21

Includes all data that have been received from analytical labs as of 10/8/99. WY99 load to 9/3/99.

The significantly higher calculated loads for WY94-95 may be the result of the preferential sampling of large runoff events. Storm-event sampling is biased toward the collection of samples during larger runoff events with higher activities as discussed in Section 4.2.1.

Relative Sub-Drainage Loads

The loading analysis in this section uses all available data for the period October 1, 1997 to date (loading period) from SW093 and the two upstream monitoring stations (GS32 and SW118). This loading analysis does not address the attenuation of actinides as they are transported from one monitoring location to the next. The

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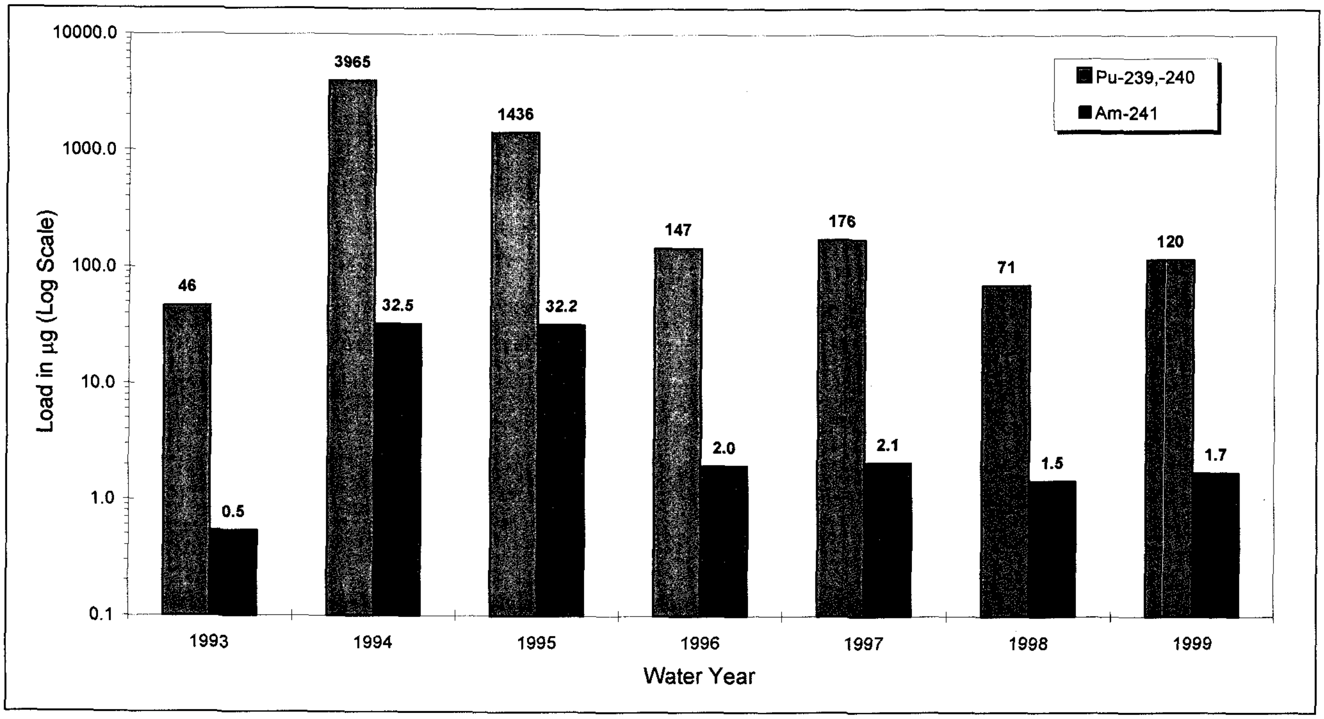
[20] Picocuries of plutonium are multiplied by 14.085 to get picograms, and converted for units to get micrograms. Similarly, picocuries of americium are multiplied by 0.3077 to get picograms, and converted for units to get micrograms.

[21] Storm-event samples are generally flow-paced composites consisting of 15 grabs taken during a direct runoff hydrograph and not during baseflow conditions. The grabs are targeted to be taken on the rising limb of a runoff period as flow rates increase to the peak. This is the period during direct runoff when the highest contaminant concentrations are expected to be measured. Under RFCA (starting 10/1/96), samples collected at POEs are continuous flow-paced composites where grab samples are collected during all flow conditions.

analysis assumes that as the period of sampling is increased, the temporal effects of actinide transport will not significantly affect the *relative* loads from the various sub-drainages. The individual sub-basins of these locations are shown in Figure 3-2 with the conceptual hydrologic connectivity shown Figure 4-14.



Includes all data that have been received from analytical labs as of 10/8/99. WY99 load to 9/4/99.

Figure 4-13. Annual Plutonium and Americium Loads at SW093: WY93 - WY99.

Monitoring location GS32 measures flows from the B779 sub-drainage area. Buildings 779, 729, 705–6, 780, 782-7, 780, and the eastern edge of 777 are all tributary to GS32. Monitoring location SW118 measures flows from a sub-drainage including the western end of North Walnut Creek and areas north and west of B371. The hydrologic connectivity of these locations is shown in Figure 4-14.

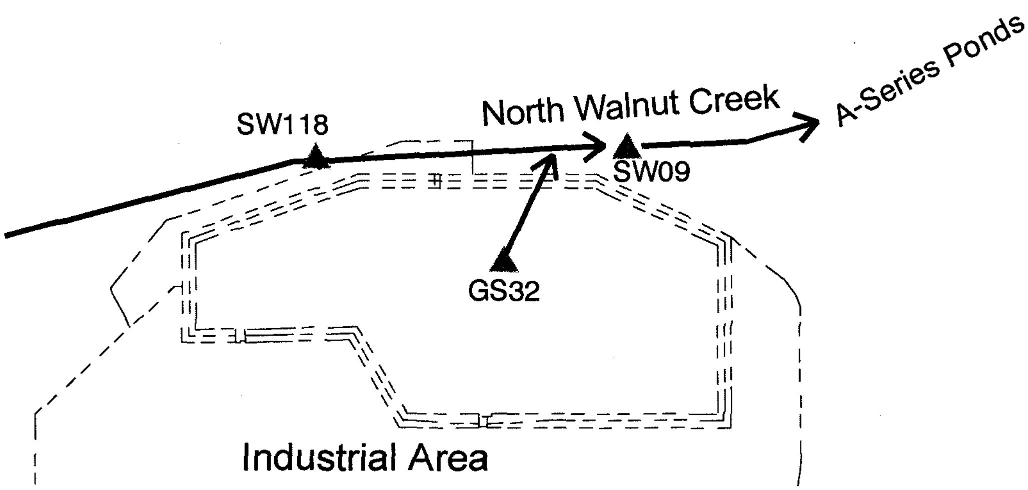


Figure 4-14. Hydrologic Connectivity of Monitoring Locations Tributary to SW093.

SW118 Sub-Drainage

Loads for SW118 were calculated by multiplying the activity for each flow-paced composite sample by the associated discharge volume, then converted to micrograms and totaled.[22] The results are given in Table 4-8.

Table 4-8. Comparison of Plutonium and Americium Loads at SW118 with SW093: WY98 to Date.

Location	Pu-239,-240 Load in μg	Am-241 Load in μg
SW093	190.8	3.21

Water Year	Pu-239,-240		Am-241	
	Load in μg	Load as a Percent of SW093 Load	Load in μg	Load as a Percent of SW093 Load
1998	3.4	4.8%	0.12	8.2%
1999	3.9	3.3%	0.05	2.9%
Total	7.3	3.8%	0.17	5.3%

Includes all data that have been received from analytical labs as of 10/8/99. WY99 load to 8/12/99.

GS32 Sub-Drainage

Since GS32 is a Performance Monitoring location without flow measurement, collecting time-paced storm-event composite samples, both flow and representative average surface-water activities needed to be estimated to calculate estimated loads.[23]

Since there is no direct flow measurement at GS32, the discharge for the loading period was estimated using seasonal runoff coefficients and measured Site precipitation. Seasonal runoff coefficients (total runoff depth divided by total depth of precipitation) were calculated using flow data from GS38 (the GS38 sub-drainage has similar characteristics to the GS32 sub-drainage[24]) and arithmetic average precipitation from nine Site precipitation gages. These seasonal runoff coefficients were then used to estimate the GS32 discharge volumes

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[22] Continuous flow-paced composite sampling began at SW118 on 11/30/97. The load for the period 10/1/97 to 11/30/97 was estimated using the measured flow volume and the volume-weighted average activity for WY98 during sampling (11/30/97 – 9/30/98).

[23] GS32 was initially installed as a Performance monitoring location in support of the B779 D&D. The decision rule for Performance monitoring calls for the comparison of individual sample results over time to evaluate for acute (short-term) changes in water quality. Since flow measurement is not a requirement for this decision, coupled with the difficulty of installing a flow measurement device (e.g. flume or weir) at this location, time-paced sampling is initiated when runoff from a precipitation event is detected, but not measured. Samples are analyzed in an attempt to analyze one runoff event per month, with a bias toward larger events.

[24] GS38 is located on Central Avenue Ditch just east of 8th Street. The sub-drainage is of a similar grade and percent impervious area. The GS38 sub-drainage included portions of the 100, 400, and 600 Areas.

for the loading period based on measured precipitation. By area, the GS32 sub-drainage is 3.2% (6.97 acres) of the total SW093 drainage area (219.2 acres). The method estimated that 1.77 million gallons (1.4% of 127.2 million gallons measured at SW093) were generated by the GS32 sub-drainage during the loading period.

Table 4-9. Estimated GS32 Discharge by Water Year During the Loading Period.

Water Year	GS32 Discharge Estimate (Mgals)	SW093 Discharge (Mgals)
1998	0.854	70.15
1999	0.912	57.01

WY99 discharge through 8/31/99.

In order to estimate load, a discharge volume is multiplied by the corresponding activity (concentration) and converted to micrograms. However, determining an appropriate activity for this calculation is difficult using storm-event sampling results. Table 4-10 shows all sample results to date at GS32. Storm-event sampling is biased toward the collection of samples during larger runoff events with higher activities for the following reasons:

- Samples are targeted to be collected once per month, with the emphasis on larger runoff events, and
- Larger runoff events tend to have higher activities due to increased particulate transport.[25]

Figure 4-15 shows the distribution of samples collected at GS32 during the loading period compared to the peak flow rate (a measure of storm intensity) at GS40.[26] From this figure, it can be seen that many of the larger events during the loading period were sampled, while the majority of the smaller runoff events were not. In fact, five of the seven largest events during the covered period were sampled at GS32. A simple arithmetic average of the sample results would be expected to overestimate the overall activity of the GS32 runoff. However, the larger runoff events also represent much larger volumes of runoff, so the associated activity of the larger events would have more influence on the overall activity after volume-weighting. Due to this difficulty in determining the true overall activity for the GS32 runoff, the following loading analysis uses several methods to estimate the overall GS32 runoff activity. Therefore, load estimates indicate a range of possible GS32 load contributions to SW093.

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[25] Actinides transported by surface water are generally associated with particulate matter. During larger runoff events, increased flow rates and precipitation intensity will suspend and mobilize larger quantities of particulate matter, and the associated actinides. See Section 6 for detail.

[26] GS40 measures runoff from the sub-drainage adjacent to the GS32 sub-drainage immediately southwest. The GS40 sub-drainage has characteristics similar to the GS32 sub-drainage, and includes the southern 700 Area. It is assumed that the runoff intensity at GS40 is proportional to the runoff intensity at GS32. GS40 began operation in March 1998; therefore, only those GS32 samples after March 1998 are displayed.

Table 4-10. Analytical Results from Samples Collected at GS32 to Date.

Sample Date	Pu-239,-240 Activity (pCi/L)	Pu-239,-240 2σ Error (pCi/L)	Am-241 Activity (pCi/L)	Am-241 2σ Error (pCi/L)
4/25/97	0.960	0.067	0.630	0.035
5/22/97	0.180	0.022	0.330	0.032
6/6/97	0.387	0.071	0.237	0.061
7/28/97	2.550	0.315	0.937	0.206
10/12/97	0.130	0.041	0.060	0.031
1/22/98	0.037	0.025	0.041	0.027
4/15/98	1.750	0.295	0.620	0.137
5/8/98	1.010	0.203	0.390	0.093
5/22/98	6.970	1.010	3.260	0.473
6/4/98	0.241	0.078	0.281	0.088
6/14/98	0.230	0.072	0.246	0.082
7/22/98	2.900	0.440	1.640	0.282
7/25/98	2.590	0.413	0.946	0.171
10/4/98	0.409	0.114	0.141	0.078
11/2/98	0.024	0.021	0.033	0.035
2/11/99	0.124	0.052	0.143	0.060
5/20/99	4.920	0.826	3.540	0.676
7/24/99	11.50	1.940	3.960	0.622
7/31/99	5.870	0.892	3.450	0.528
8/28/99	1.130	0.218	1.120	0.213
9/2/99	1.460	0.266	0.944	0.188

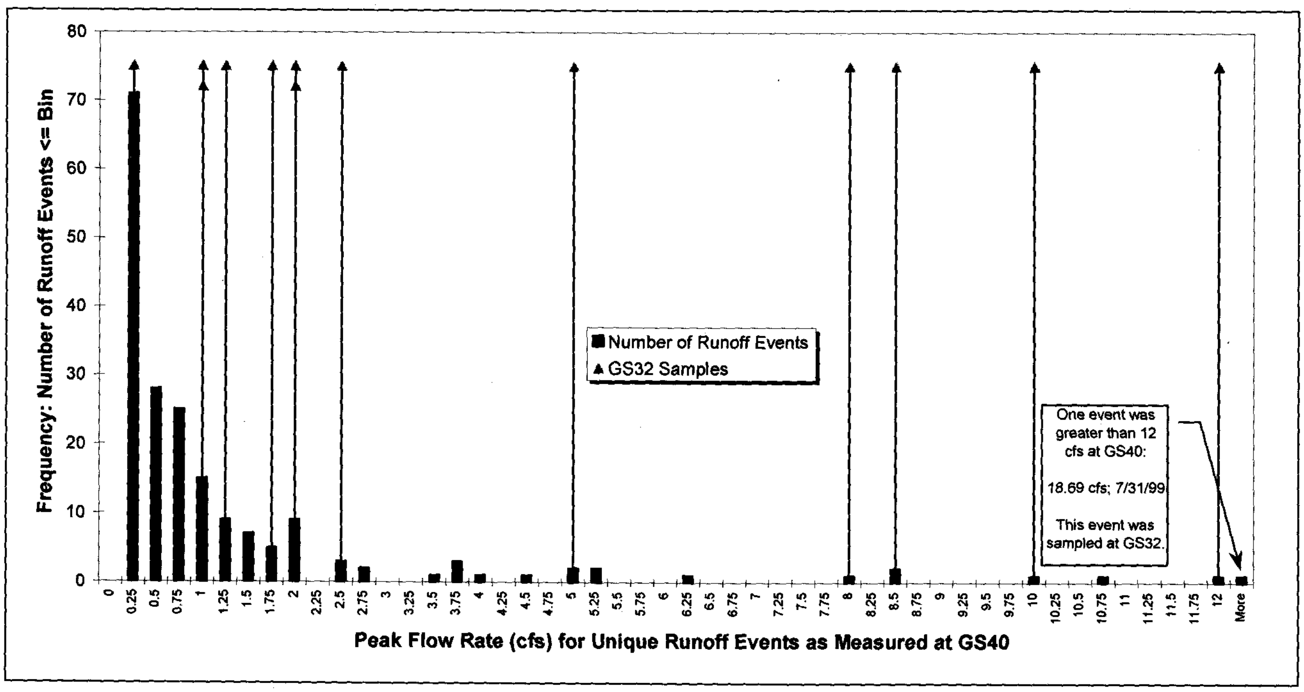

Figure 4-15. Distribution of Samples from GS32 Compared to Peak Flow Rate at GS40.

Using the arithmetic average of the results presented in Table 4-10 (2.161 pCi/L plutonium; 1.093 pCi/L americium) the loads in Table 4-11 are estimated.

Table 4-11. Comparison of Plutonium and Americium Loads at GS32 with SW093: WY98 to Date (Average GS32 Sample Activity).

Location	Pu-239,-240 Load in μg	Am-241 Load in μg
SW093	190.8	3.21

Location	Pu-239,-240		Am-241	
	Load in μg	Load as a Percent of SW093 Load	Load in μg	Load as a Percent of SW093 Load
GS32	203.4	>100%	2.25	70.1%

Using the median of the results presented in Table 4-10 (1.01 pCi/L plutonium; 0.62 pCi/L americium) the loads in Table 4-12 are estimated.

Table 4-12. Comparison of Plutonium and Americium Loads at GS32 with SW093: WY98 to Date (Median GS32 Sample Activity).

Location	Pu-239,-240 Load in μg	Am-241 Load in μg
SW093	190.8	3.21

Location	Pu-239,-240		Am-241	
	Load in μg	Load as a Percent of SW093 Load	Load in μg	Load as a Percent of SW093 Load
GS32	95.1	49.8%	1.28	39.9%

The seasonal arithmetic average activities of the results presented in Table 4-10 are given in Table 4-13. The corresponding estimated loads are presented in Table 4-14.

Table 4-13. Average Seasonal Activities for GS32 Sample Results.

Season	Average Pu-239, -240 Activity (pCi/L)	Average Am-241 Activity (pCi/L)
Fall (Sep, Oct, Nov)	0.506	0.295
Winter (Dec, Jan, Feb)	0.080	0.092
Spring (Mar, Apr, May)	2.632	1.462
Summer (Jun, Jul, Aug)	3.044	1.424

Table 4-14. Comparison of Plutonium and Americium Loads at GS32 with SW093: WY98 to Date (Average Seasonal GS32 Sample Activity).

Location	Pu-239,-240 Load in μg	Am-241 Load in μg
SW093	190.8	3.21

Location	Pu-239,-240		Am-241	
	Load in μg	Load as a Percent of SW093 Load	Load in μg	Load as a Percent of SW093 Load
GS32	223.7	>100%	2.48	77.3%

In an attempt to estimate the overall *volume-weighted* average activities of the runoff at GS32, the following method was used. Since runoff activities generally increase with storm-event intensity, relationships between GS32 actinide activity and peak flow rate measured at GS40 were evaluated (Figure 4-16). Although the linear curve fits do not show strong correlations, the fits were used with an understanding of the associated error.

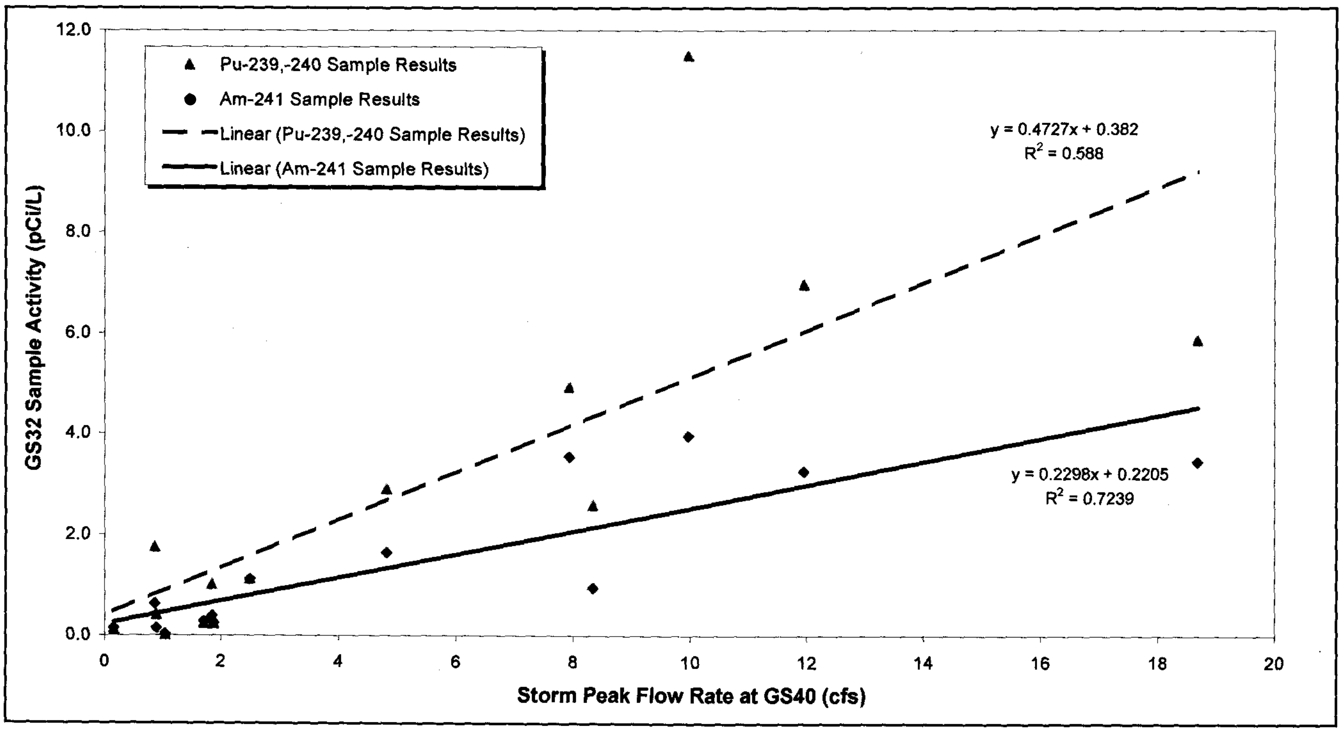

Figure 4-16. Relationship of GS32 Sample Results with Corresponding Runoff-Event Peak Flow Rate.

Using the correlations from Figure 4-16, an estimated activity at GS32 for each runoff event during the period of record at GS40 (in this case March 1998 to Date) can be calculated. Furthermore, if it is assumed that the direct runoff volume for each event at GS40 is proportional to the direct runoff volume for each event at GS32, then an

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overall volume-weighted activity at GS32 can be estimated using the calculated activity for each event and the corresponding direct runoff volume.[27]

Using the estimated volume-weighted activities from this analysis (2.003 pCi/L plutonium; 1.008 pCi/L americium), the loads in Table 4-15 are estimated.

Table 4-15. Comparison of Plutonium and Americium Loads at GS32 with SW093: WY98 to Date (Median GS32 Sample Activity).

Location	Pu-239,-240 Load in μg	Am-241 Load in μg
SW093	190.8	3.21

Location	Pu-239,-240		Am-241	
	Load in μg	Load as a Percent of SW093 Load	Load in μg	Load as a Percent of SW093 Load
GS32	188.6	98.8%	2.07	64.5%

Summary

The loading analysis results for relative loads of upstream automated-monitoring locations compared to SW093 are given in Table 4-16 and Table 4-17. Ranges are given for GS32 as a result of the various methods used to determine the overall GS32 runoff activity as detailed in the previous section.

Table 4-16. Comparison of Plutonium Loads at GS32 and SW118 with SW093: WY98 to Date.

SW093	
Water Year	Pu-239,-240 Load in μg
1998	71.2
1999	119.6
Total	190.8

Water Year	GS32		SW118	
	Pu-239,-240 Load in μg	Load as a Percent of SW093 Load	Pu-239,-240 Load in μg	Load as a Percent of SW093 Load
1998	46.0 – 115.1	64.6 – >100%	3.4	4.8%
1999	49.1 – 108.7	41.1 – 90.9%	3.9	3.3%
Total	95.1 – 223.8	49.8 – >100%	7.3	3.8%

[27] Direct runoff is the flow volume that can be attributed to the overland flow of excess precipitation during and following a storm event. Direct runoff at GS40 was calculated by manually extracting each runoff event from the measured hydrograph and subtracting baseflow. The *straight line method* was used to estimate baseflow by drawing a horizontal line from the point where surface runoff begins to the intersection with the recession limb, based on visual inspection and professional judgement.

Table 4-17. Comparison of Americium Loads at GS32 and SW118 with SW093: WY98 to Date.

	SW093
Water Year	**Am-241 Load in μg**
1998	1.47
1999	1.74
Total	3.21

	GS32		SW118	
Water Year	**Am-241 Load in μg**	**Load as a Percent of SW093 Load**	**Am-241 Load in μg**	**Load as a Percent of SW093 Load**
1998	0.62 – 1.34	42.2 – 91.2%	0.12	8.2%
1999	0.66 – 1.16	37.9 – 66.7%	0.05	2.9%
Total	1.28 – 2.48	39.9 – 77.3%	0.17	5.3%

The calculation results presented in Table 4-16 show that the GS32 and SW118 sub-drainages contribute 54 - >100% of the plutonium load calculated at SW093. However, other sub-drainages not specifically monitored upstream of SW093 can be reasonably assumed to contribute the remaining 0 - 46% of the plutonium load measured at SW093 (0 – 88 μg plutonium). These areas include portions of the 700 Area (including B771, B774, B776, and B777), a portion of the 500 Area (including B559), a portion of the 300 Area (including B374 and B371), and a portion of the 100 Area.

The calculation results presented in Table 4-17 show that the GS32 and SW118 sub-drainages contribute 45 - 83% of the americium load calculated at SW093. However, other sub-drainages not specifically monitored upstream of SW093 can be reasonably assumed to contribute the remaining 17 - 55% of the americium load measured at SW093 (0.56 – 1.76 μg americium). These areas include portions of the 700 Area (including B771, B774, B776, and B777), a portion of the 500 Area (including B559), a portion of the 300 Area (including B374 and B371), and a portion of the 100 Area.

The loading estimates indicate that the GS32 sub-drainage may be a significant contributor to the overall loads calculated at SW093.

4.2.3. Real-Time Water Quality Data

WY99 Water Quality Data

Fifteen-minute readings of temperature, pH, turbidity, specific conductivity, and nitrate are collected by a continuously-deployed, multi-parameter water-quality probe at SW093. Daily averages of readings collected for WY99 to date are presented in Figure 4-17 and Figure 4-18. Data are not collected using standard laboratory

Y2

analytical methods and are intended only as indicators or co-indicators of change. Occasionally, negative values and single point spikes in turbidity results are removed from the data set prior to performing calculations.[28]

As shown in Figure 4-17, mean daily results for pH are steady between 7.4 and 8.0 pH units between October 1, 1998 and August 6, 1999.[29] Daily-average turbidity results indicate numerous sharp peaks of high turbidity (Figure 4-17). These turbidity peaks correspond to runoff events, the frequency and intensity of which generally increase during the spring. Specific conductivity results (Figure 4-18) also exhibit numerous peaks. The high conductivity peaks in the winter correspond to snowmelt events. This increased ionic strength can probably be attributed to salting of road surfaces and walkways. The low peaks in the spring also correspond to runoff events, and are likely due to dilution of base-flow by runoff. Finally, nitrate results (Figure 4-18) exhibit peaks during runoff events as well. However, nitrate readings are expected to exceed actual nitrate concentrations in the surface water as identified by a study of nitrate ion-specific electrodes performed by the Site (RMRS, 1997a).[30]

In conclusion, *in situ* water-quality monitoring results indicate no unusual or unexpected conditions for WY99 to date. WY99 trends for all parameters are similar to those observed in WY97 and WY98.

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[28] Negative turbidity results or single (15-minute) point spikes of high turbidity occasionally occur in the data set. Negative turbidity values can be attributed to slight calibration drift or error. These occasional values are deleted from the data set considered in averaging calculations, recognizing that they are erroneous, and simple replacement with zero would incorrectly skew the results. High individual readings, often several orders of magnitude greater than previous or following readings, which do not occur during any apparent event are referred to as single point spikes. These values can be attributed to large particles passing over the optical surface at the instant of measurement. These occasional points are also not applied to averaging calculations because they are considered not truly representative of the water turbidity for the 15-minute period.

[29] There is a gap in the data set in December and January; the probes were removed from field service during this period to prevent damage due to freezing in the stream reach.

[30] Nitrate ion specific electrode (ISE) measurements suffer from limited accuracy and precision in the concentration range observed in Site surface waters. Inaccuracies in nitrate ISE measurements are caused by significant interferences associated with common surface-water constituents including chloride and natural organic matter. Wet chemical field tests have been performed to verify this limitation, and collection and interpretation of nitrate results have been optimized.

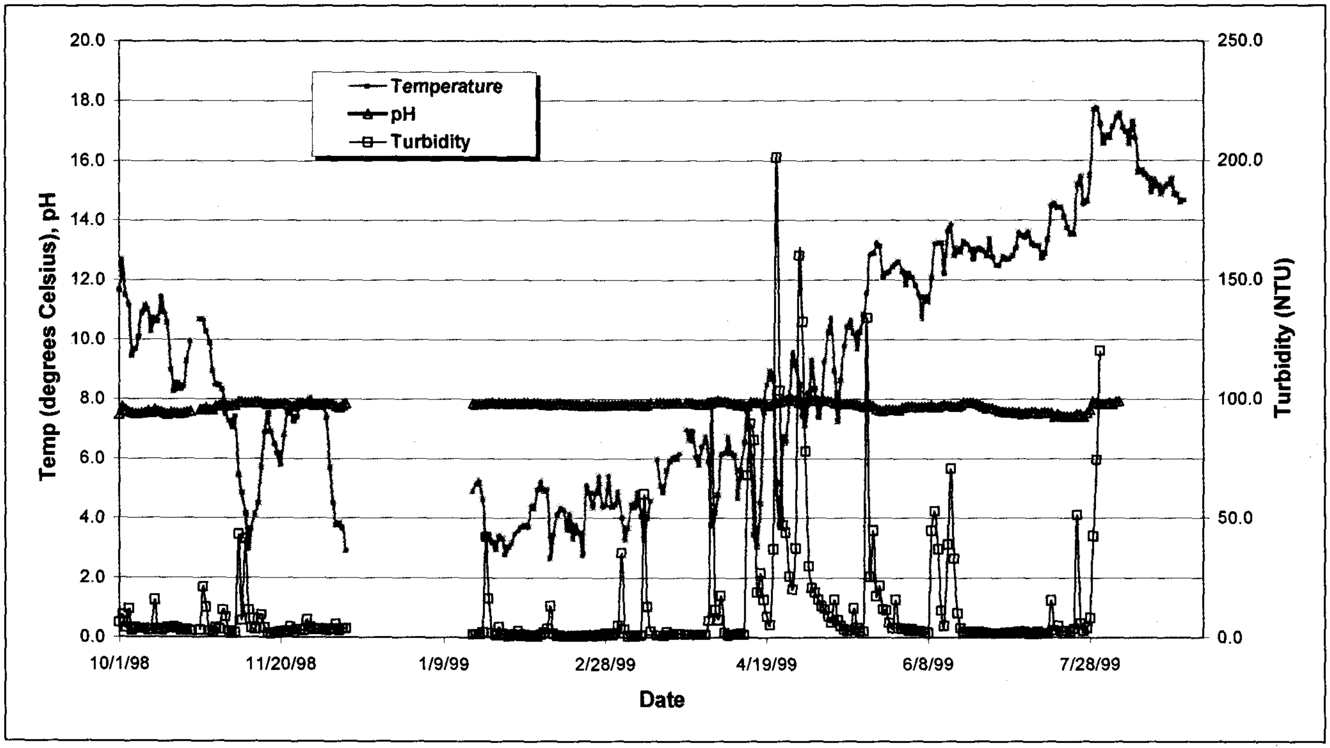

Figure 4-17. Mean Daily Temperature, pH, and Turbidity at SW093 for WY99 to Date.

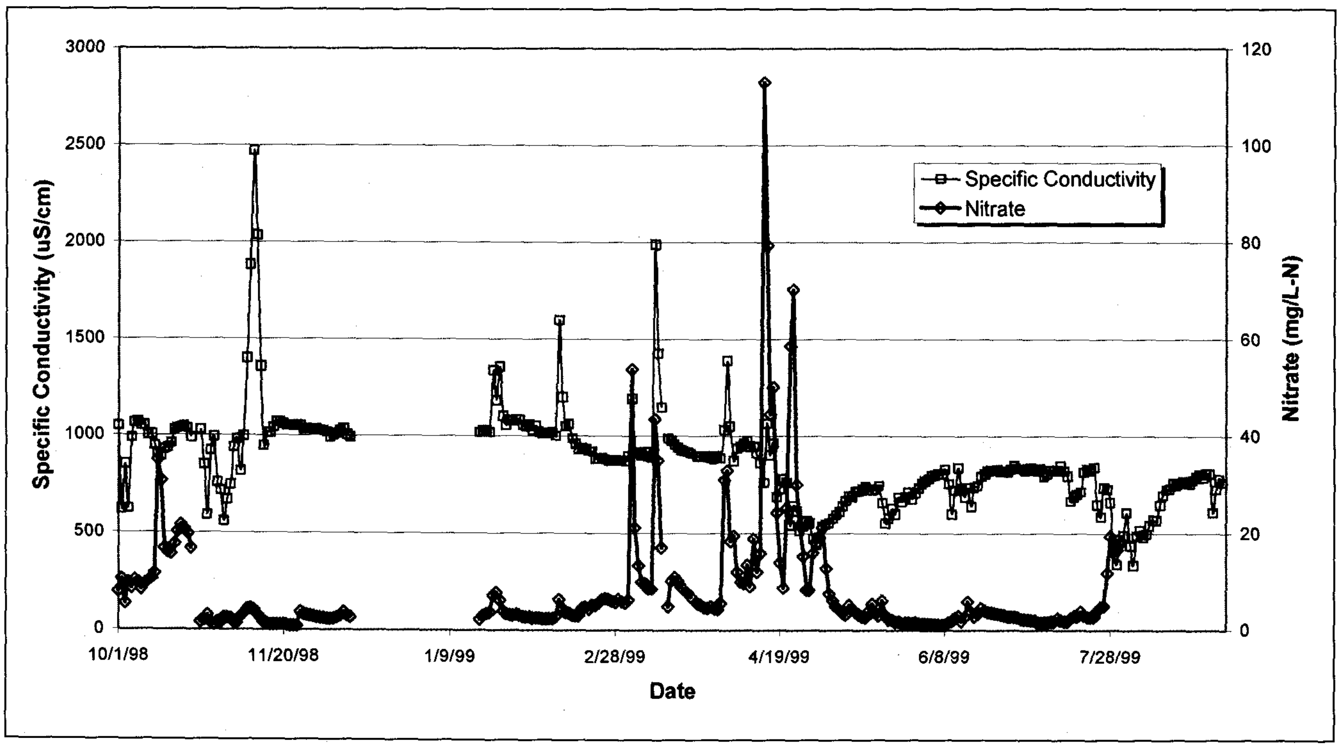

Figure 4-18. Mean Daily Specific Conductivity and Nitrate at SW093 for WY99 to Date.

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Water Quality Correlations

Continuous, real-time water-quality measurements of pH, specific conductivity, turbidity, temperature, and nitrate are taken at 15-minute intervals at POE SW093. Comparisons of this data with SW093 radionuclide activities were made to identify any possible correlations as part of this source evaluation. In the event that a reasonable correlation ($R^2 > 0.7$ for environmental data) were discovered, additional investigation would be initiated to utilize this information. Because directly-comparable data sets are not (and cannot reasonably be) collected up-gradient for comparison, such a correlation would not immediately pinpoint a source. Such a correlation, however, might be used to direct further investigation. For example, if a correlation between nitrate and plutonium were observed, efforts might be focussed upon identifying possible up-gradient areas where plutonium nitrate may exist. This section describes how these comparisons were made, presents the results, and offers preliminary conclusions of the findings.

Flow-Weighting of Water Quality Data

Radionuclide activity data from SW093 represent activities as measured in flow-paced, composite samples. In contrast, real-time water-quality data are collected as discrete, time-paced results. Consequently, simple, direct comparison of these data sets is inappropriate.

To facilitate comparison of these data sets, water-quality results were converted to flow-paced averages. Individual 15-minute water-quality results were multiplied by the corresponding 15-minute flow-rate measurements. These products were then summed over the period of each flow-paced composite-sample duration and divided by the sum of the flow rates over the same period. This operation is summarized simply by the following equation:

$$\frac{\sum\left(WQ_{15\,Min.} \times Flow_{15\,Min.}\right)}{\sum\left(Flow_{15\,Min.}\right)}, \text{ where}$$

$WQ_{15\text{ Min.}}$ = Individual 15-minute water quality parameter reading

$Flow_{15\text{ Min.}}$ = Individual 15-minute flow rate measurement, and

Summations are computed over the duration of the corresponding composite sample period.

This operation was performed for all water-quality parameters for each composite sample collected during WY99. In recognition of periodic gaps in the water-quality data set due to calibration activities and probe malfunctions, flow-paced results with more than 5% of the time-series data missing were not used in the correlation analyses.

To determine the success and applicability of this flow-weighting technique, a performance check was completed. Because TSS is analyzed (when permitted by hold time) from the flow-paced composite samples, these values are inherently flow-paced results. If the flow-weighting technique was successful, these TSS values may be expected to correlate well with the flow-weighted turbidity values[31]. TSS results were plotted against both the flow-weighted turbidity data and the non-flow-weighted, time-paced averages of turbidity. This plot is shown in Figure 4-19.

Figure 4-19 demonstrates an excellent correlation between the TSS and flow-weighted turbidity values, while proving a poor correlation between the TSS and non-flow-weighted turbidity data. This result simultaneously offers confidence in the applied flow-weighting technique and reinforces the need for flow-weighting of time-paced data.

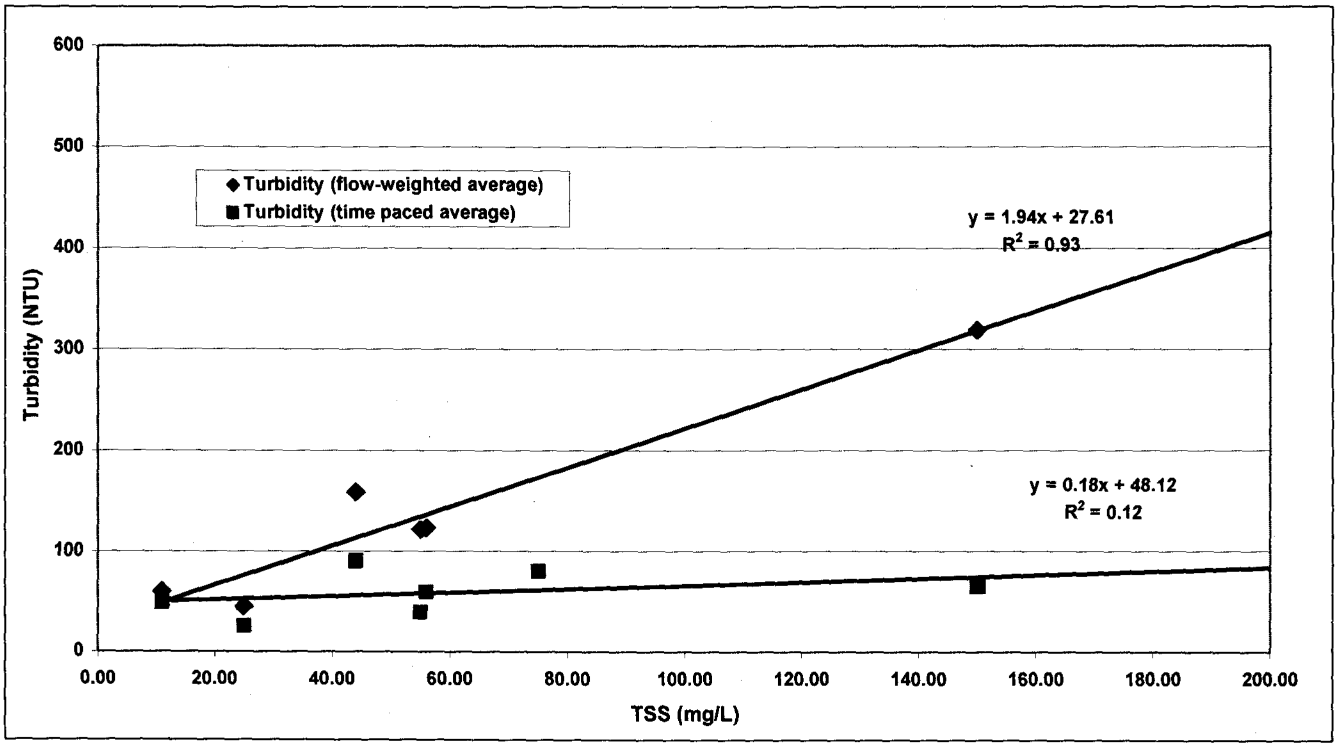

Figure 4-19. Check of Flow-Weighting Technique: Turbidity vs. TSS at SW093.

Results

Flow-weighed water-quality data for WY99 are plotted against plutonium activities from flow-paced, composite samples in Figure 4-20. No apparent correlations were observed for any of the water-quality parameters with plutonium activity. Similar comparisons were made between composite sample average flow rate and the flow-weighted water-quality parameters. Fairly good correlations were observed for turbidity and specific conductivity as compared to flow rate, with turbidity increasing and specific conductivity decreasing with increasing average flow rates. Unfortunately, these results offer no specific insight as to the locations of the source(s) of radionuclide activity observed at SW093.

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[31] Though there are important differences between the measurements of TSS and turbidity, a rough correlation between the two values is expected.

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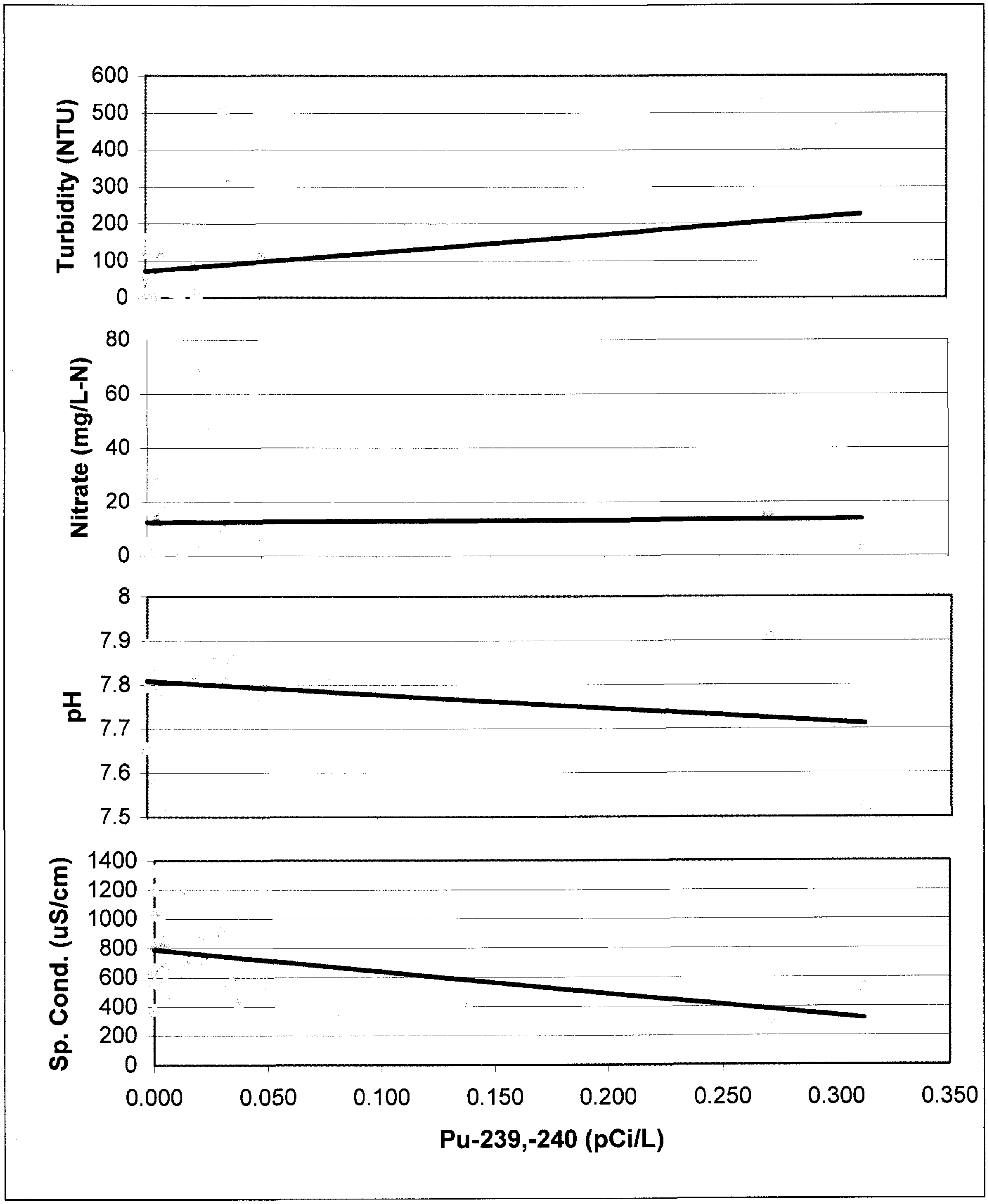

Figure 4-20. Flow-Weighted Water-Quality Data as a Function of Plutonium Activity in Composite Samples from SW093: WY99 to Date.

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4.3. SOIL AND SEDIMENT INFORMATION

A review of historical reports and analysis of historic data provided the basis for this review of soil and sediment plutonium activities within the SW093 drainage basin in Progress Report #3 (RMRS, 1997e). Figure 4-21 shows the activity for soil and sediment sampling locations tributary to SW093.

The data plotted in Figure 4-21 indicate several orders of magnitude difference in plutonium activities for contaminated soils and sediments tributary to SW093. The highest plutonium value, 115.3 pCi/g, was measured at sampling location PCB29, along the northeast perimeter of B779. The B779 sub-drainage (GS32 sub-drainage) also shows four locations exceeding 10 pCi/g Pu, and seven locations above 1 pCi/g Pu.

Other areas with soil/sediment activities exceeding 1 pCi/g Pu are:

- The area surrounding B774 shows 3 locations above 1 pCi/g and 1 location above 10 pCi/g;
- The area north of B776 shows 6 locations above 1 pCi/g and 1 location above 10 pCi/g; and
- The areas near B559 and B575 show two locations above 1 pCi/g.

5. ASSESSMENT OF RECENT SITE PROJECTS

Site closure activities including building D&D work, ER projects, excavation work, and routine day-to-day operations are ongoing at multiple locations around the Site. Those activities and projects conducted during the June through August time period (FY99) in the 100, 200, 300, 500, and 700 areas were reviewed and assessed to determine if they represented a plausible source of the plutonium that resulted in the elevated activities observed at monitoring location SW093.

5.1. BUILDING OPERATIONS AND D&D WORK

D&D project activities occurred throughout the Site during FY99. D&D Projects in the 700 Areas could have contributed radiological contamination to the SW093 sub-drainage. Projects and operations in the 300 and 500 Areas were also examined. For all Areas, the Site Shift Super's Daily Reports were reviewed to identify any events that may have contributed plutonium contamination to North Walnut Creek. For ongoing D&D projects, project documentation was reviewed, project managers were contacted, and Site closure activities were examined. This information was used in conjunction with water-quality sampling results to assess whether or not there was a connection between D&D projects and elevated plutonium activity measured in the runoff at downstream monitoring locations. The D&D projects and operations in the 300, 500, and 700 Areas that could have impacted surface water in the SW093 drainage basin are discussed in the following sections.

5.1.1. 300 AREA

Buildings 371/374

The original mission of B371/374 consisted of three elements: 1) to replace the plutonium-bearing residue recovery and waste operations in B771 and B774; 2) to recover plutonium from weapons returned from the stockpile; and 3) to provide large-scale storage of plutonium and plutonium-bearing materials. (Building 371 Web Page: History; 1999)

Since the termination of all nuclear production operations at the site in 1989, B371 has been used primarily for the storage of plutonium and uranium metal, oxide, residues, transuranic (TRU) wastes, low-level wastes (LLW), and Resource Conservation and Recovery Act (RCRA) regulated mixed wastes and residues. SNM is stored in the Central Storage Vault (CSV), vault-type rooms, and other designated areas. B374 has continued to conduct waste processing operations. (Building 371 Web Page: History; 1999)

For the June through August 1999 period, B371 conducted routine building operations, residue stabilization projects, and deactivation activities. There were no unplanned events, spills, or off normal conditions that would have caused the release of radiological contamination to surface waters during this time period. There were two planned core drillings of an outside wall to install a chiller. Soil disturbance permits were obtained for the installation. The project had all the required Site approvals. (Ward, 1999a)

5.1.2. 500 AREA

Building 559

B559 contains laboratory facilities used to perform analyses of samples from waste production processes, and products from all areas at the Site.

Between June and August 1999, B559 conducted routine laboratory operations and had no unplanned events, spills, off-normal conditions, or soil disturbances. There was one approved incidental waters disposition. Condensate from dehumidification processes in a non-radiological area was released to the ground on July 10, 1999. (Ward, 1999b)

A thorough review of the B559 operational records by the Facility Manager (Hunter, 1999) did not reveal any events which involved spills or releases to the environment during this time period.

5.1.3. 700 AREA

Building 707

B707 houses what was formerly the main weapons components production facility at the Site

Between June and August 1999, B707 conducted routine building operations, residue stabilization projects, and deactivation activities with no unplanned events, spills, or off-normal conditions that would of cause releases to the surface waters. No soil disturbances or incidental water activities were associated with B707 during the June to August 1999 time period. (Ward, 1999c)

Building 729

B729 was constructed in 1971 as a support facility for B779. B729 contained a filter plenum and an emergency electric power generator. B729 was connected to B779 via a second story bridge.

No known liquid radioactive effluent releases occurred during building strip-out. Airborne activity monitoring was performed during the strip-out of radioactively contaminated equipment from B729. This included continuous effluent air monitoring on the stack. Final radiological surveys were performed on the building prior to its demolition. The building was radiologically surveyed and determined to be free-releasable prior to demolition. All surveys indicated that the building interior and exterior surfaces were well below the DOE Order 5400.5 release limits for transuranics. (Grube, 1999)

Buildings 771/774

B771 houses the primary plutonium recovery facility at the Site. Plutonium recovery processes are no longer being utilized in B771, although the gloveboxes and equipment are still in place. B771/774, a former plutonium processing facility, in undergoing D&D under the authority of a CDPHE-approved Decommissioning Operations Plan (DOP).

There is no evidence of any off-normal event in B771 or B774 that released radiological contamination to the environment during the June through August, 1999 time frame. This statement is based on the personal records of Leslie Langlois (Environmental Compliance), her review of B771 and B774 Configuration Control Authority (CCA) records and her interview with the CCA of B771 and B774. (Schweitzer, 1999)

Buildings 776/777

B776 and B777 contain facilities such as waste-size reduction, supercompaction, waste collection tanks, nuclear material handling and packaging, utilities, and preventative maintenance.

During the June through August 1999 period, no B776/777 D&D project activities were performed. Operations were limited, as the B776/777 Complex has been shut down since July, although some container movement has occurred since then. However, there has been some container gas generation testing. Two projects of note were the installation of a compressor, which involved the pouring of a concrete pad on an asphalt surface, and some steam work in B710 which is a non-radiological building. None of these activities appear to have caused soil disturbance that may have resulted in a release of radioactivity into the air or surface water. (Brown, 1999)

Building 779

B779 houses what was formerly production, plutonium recovery, and research and development facilities related to weapons production. B779 is presently going through deactivation and will eventually complete the entire deactivation, decontamination, and decommission process. The deactivation process includes glovebox stripout, disposition of excess chemicals, decontamination, etc. The remainder of activities in B779 involve maintaining the building safety envelope.

B779 was constructed in 1965 and expanded in 1968 (779A) and 1973 (779B). B779 was used as a Research and Development center in support of nuclear weapons production. B779 contained process equipment that modeled some of the production facility's mission, and laboratory equipment to conduct material and environmental testing. B779 was erected over the site of one of the original Solar Evaporation Ponds which was likely to have caused the uranium contamination (11 to 150 dpm/l) that was detected during the construction of the building. (RMRS, 1998c)

5.2. ER PROJECTS

Historically, there have been numerous radioactive releases to the A-series ponds that may have potentially contaminated the soil and sediment in the SW093 basin. The Environmental Restoration Solar Ponds Plume project, which just completed the construction phase, may have affected the migration of these contaminants from their source of origin.

5.2.1. Solar Ponds Plume

Five Solar Evaporation Ponds, located in the northeast corner of the Protected Area, were used to store and evaporate radioactive and hazardous liquid wastes. These ponds were drained and sludge removal was completed in 1995. To de-water the hillside, six interceptor trenches were installed in 1971. The original six trenches were abandoned in place and the current Interceptor Trench System (ITS) which was installed in 1981. The ITS is generally keyed into bedrock and effectively collects most of the water; however, up to one third of the groundwater underflows the collection system, and eventually discharges to North Walnut Creek. (Primrose, 1999)

The Solar Pond nitrate plume has a greater areal extent than the uranium plume. The data suggest that the uranium in groundwater near North Walnut Creek is naturally occurring and not part of the uranium plume. The highest concentrations of uranium are found adjacent to the Solar Ponds, while the higher concentrations of nitrates are found at a greater distance from the ponds. (Primrose, 1999)

The Solar Ponds Plume project began in June and continued through September. Contaminants were nitrate and uranium in groundwater. No contaminants above action levels were detected in soils and weekly radiological surveys of equipment came up below background. No releases to the streams occurred except for stormwater runoff during the heavy rains in early August. (Primrose, 1999)

5.3. ROUTINE SITE OPERATIONS

Site Utilities operates the domestic water treatment system, steam production, nitrogen production (and affiliated distribution systems for each of these processes), raw water distribution, natural gas distribution, propane tank supplies, and high voltage system maintenance. None of the routine activities involved radiological operations.

No excavations were under Utilities control during this period. All surface water impacts resulting from routine pit/containment draining/pumping were minimized by actions conducted with the concurrence and approval of the surface water division. All waters were dispositioned either to ground or to sanitary sewers as directed by RMRS Surface Water.

A review of operational data for the June through August 1999 timeframe by the Site Utilities manager (Landry 1999) offered no evidence that the Utilities Operation adversely impact the environment with radiological contamination.

5.3.1. Liquid Waste Operations

Liquid Waste Operations transferred liquids across the Site via tanker trucks, dumpsters, and through pipelines; however, no spills or releases to the environment occurred during this timeframe. (Vess, 1999)

5.3.2. Incidental Waters and Internal Waste Streams Programs

During June 1 through August 31, 1999, 46 incidental waters (IWs) were sampled and dispositioned. All were associated with routine Site activities such as accessing utility pits and pumping out transformer berms. These IWs were assessed using field measurements and chemical analyses for known or suspected contaminants to determine appropriateness for discharge to the environment. Eighteen (18) IWs were discharged to the SW093 drainage following receipt of analytical results. Although isotopic characterization was not part of the assessment of these waters, measurements for gross alpha and gross beta indicate that discharge to the environment would not have significantly impacted radionuclide activity measured at SW093. The remaining IWs required treatment and were routed to various Site treatment facilities. (Barker, 1999)

To the best of the Site's knowledge, there were no spill events recorded during this time period that may have introduced radioactive contamination to the SW093 drainage. A review of the Shift Superintendent Daily Reports indicates that spills of potentially radiologically contaminated materials were confined to the interior of buildings and adequately contained and cleaned up without threat of discharge to the environment. Additionally, the annual Source Control Reviews, which involve a walkdown of all areas outside buildings within the Industrial Area to identify potential surface water contamination sources, were completed June 23, 1999. There were no findings or observations that suggested off-normal conditions that would have resulted in elevated radionuclide measurements at SW093.

5.4. SUMMARY OF RECENT SITE ACTIVITIES IMPACT ON SW093

For the reasons outlined above, there is no reason, at this time, to suspect that recent D&D, ER Projects, excavation, or routine Site operations caused a release of plutonium or americium, resulting in the elevated activities measured at SW093.

6. ACTINIDE MIGRATION EVALUATION

The Site has initiated a comprehensive multi-year Actinide Migration Evaluation (AME) to improve understanding of the behavior and transport of plutonium, americium, and uranium in the environment. One of the expressed goals of the AME is to quantify the rates of actinide migration via different environmental pathways to explain recent measured quantities of actinides in Site surface-waters and to recommend mitigation activities to minimize impacts to surface-water quality.

6.1. CURRENT RESEARCH ACTIVITIES

The AME group collected stormwater runoff from GS10 to assess the particle-size distribution of plutonium in suspended solids and to evaluate the characteristics of plutonium-containing particles in surface-water. Approximately 300 liters of water were collected in April for ultrafiltration with various nominal pore-size ultrafilters by Texas A&M researchers. The filtered particles will be analyzed for actinide activity, selected metals, organic carbon, and surface charge. These data should provide clues as to the sources of the plutonium-contaminated particles and how their transport might be controlled. A final report was provided to the Site in September 1999; a summary of results is given in Section 6.2.

The Colorado School of Mines researchers began investigating the properties of Site soil aggregates and the affect of disaggregation on actinide migration. This investigation will determine the dominant forms of materials that bind smaller, primary soil particles into larger soil particles. Knowledge of the aggregating properties of the Site soils will lend insight to the mechanisms by which plutonium-contaminated soils are moved by natural processes such as freeze-thaw cycling, raindrop impact, erosion and sediment transport.

Colorado School of Mines researchers also investigated how changes in oxidation/reduction (redox) conditions affect plutonium mobility. This investigation is largely applicable to environments such as wetlands, pond bottom sediments, and saturated sub-surface (shallow/perched groundwater) areas that are contaminated with actinides. Therefore, this study might not be useful for assessing source terms for SW093 plutonium, but it may be helpful for evaluating what happens to the plutonium-contaminated sediments when they are deposited in deep-water or wetland environments that are present in Site detention ponds. A final report on this research was provided to the Site in September 1999; a summary of results is given in Section 6.2.

Further, the AME Team is calibrating mathematical models to estimate actinide movement via soil erosion (i.e. via water) and by wind re-suspension and air transport. The soil erosion model will be linked to a sediment transport model (Hydrologic Efficiency Code-Version 6T (HEC-6T)) to estimate sediment and associated actinide transport in Site streams. The Water Erosion Prediction Project (WEPP) model is not designed to estimate erosion from industrial surfaces such as those that drain to SW093, but data from SW093 for both suspended solids and plutonium activity will be used in HEC-6T to estimate the potential for transport of plutonium in Site watersheds. The models will be completed by November 30, 1999; and their results may be used to compare actinide loading at SW093 to other Site source terms.

6.2. SUMMARY OF ACTINIDE MIGRATION EVALUATION RESULTS TO DATE

Soils from the 903 Pad and Lip Area were evaluated using selective chemical extraction methods that test plutonium's association with major, chemically distinguishable soil fractions — namely, exchangeable, carbonate, sesquioxide, organic, and residual fractions. Again, the methodology and protocols are limited to the background value of approximately 0.05 pCi/g plutonium. The following findings are potentially relevant to this source evaluation:

- Activities (pCi (plutonium and americium) per gram of soil) in the various soil fractions show a nearly three order-of-magnitude range in activity within any particular sample;
- Partition coefficients for soil/sediment-water system (ranging from 10^4 to 10^5 L/kg) suggest that plutonium and americium are strongly bound to particulates, and are likely mobilized by physical transport mechanisms, not by dissolution under normal conditions.

More recent significant conclusions from the Actinide Migration Evaluation which are relevant to this source evaluation are as follows:

- Colorado School of Mines researchers released experimental results that indicate plutonium and americium solubility in soils does not increase in strong reducing environments (i.e. low oxygen content). This means that waterlogged soils or wetland environments should not necessarily be regarded as areas with high actinide mobility. AME data suggest that actinide solubility actually decreases with decreasing Eh (redox potential).
- Los Alamos National Laboratory researchers determined that the plutonium in the Site environment is predominantly in the +4 oxidation state. Therefore, the plutonium is in the form of PuO_2, which is extremely insoluble and will be transported as a particulate, not a dissolved specie.
- Texas A&M researchers found that plutonium at femptocurie levels (fall out levels) is present almost entirely in colloidal form in Walnut Creek water discharged from the Site. Stormwater sampled from

GS10 in April 1999 was processed by ultrafiltration with subsequent actinide analysis of both the filter passing and filter-retained particles. These samples indicated that about 70 percent of the plutonium in suspension is in colloidal form in the stormwater. This particle size should not settle as a primary particle in a detention pond. However, the fact that the ponds do settle out the actinides implies that there is a mechanism by which the colloids are aggregated into secondary particles which are large enough to settle. This mechanism will be studied in FY00.

- Colorado School of Mines researchers determined that Site soil aggregates are predominantly held together with organic materials, not iron and manganese oxide cements. Further work will determine what happens to the plutonium particle-size distribution when the soils are disaggregated by different physical and chemical processes. The results of this research are expected to be delivered in November 1999.

6.3. UPCOMING ACTINIDE MIGRATION EVALUATION ACTIVITIES

The near-term (FY00) scope of work for the AME effort includes several elements applicable to this source investigation:

1. Complete soil aggregation and phase speciation studies to determine chemical speciation of plutonium;
2. Analyze surface-water samples to learn about the disaggregation and aggregation processes controlling transport of colloidal actinides in surface water;
3. Analyze actinide leaching potential for concrete samples from contaminated buildings to support D&D projects;
4. Complete groundwater geochemical modeling, and collect groundwater samples from meticulously installed monitoring wells (a.k.a. aseptic wells) to determine magnitude of groundwater transport pathway;
5. Complete erosion, sediment, and air transport modeling for both present and future Site configurations.

The surface-water Source Evaluation team will continue to consult regularly with the Actinide Migration Evaluation Team to remain up-to-date as to the latest findings as well as offer recommendations and insight into possible areas of research.

7. SW093 SOURCE LOCATION ANALYSIS SUMMARY

7.1. RESULTS

In the following section, a discussion of source hypotheses for SW093 is presented. Since this report builds on the results of the previously completed reports for the Walnut Creek Source Evaluation, the reader is referred to the following reports for background: Progress Reports #1, #2, #3 (RMRS, 1997c, 1997d, 1997e), and the *Final Report to the Source Evaluation and Preliminary Mitigation Plan for Walnut Creek* (RMRS, 1998a). No singular actinide/radionuclide source of the elevated 30-day averages at SW093 has been identified. Available data and information do not confidently point to any singular conclusion. In fact, it is likely that multiple sources and transport mechanisms are responsible for the elevated radionuclide activities at SW093. However, current data evaluation does point to certain sub-drainage *areas* that may be major contributors of actinide load to SW093.

Data from *in-situ* real-time water-quality monitoring at SW093 were evaluated for indications of causes of the recent elevated actinide measurements at SW093. However, *in-situ* water-quality monitoring results gave no indication of off-normal or unusual conditions during WY99. WY99 trends for all parameters are similar to those observed in WY97 and WY98.

For the reasons outlined in Section 5, there is no reason to suspect that D&D, ER Projects, excavation, or routine Site operations caused a release of plutonium or americium that resulted in the elevated activities measured at station SW093. Rather, it appears that the elevated activities are consistent with plutonium source(s) originating from historical Site operations mobilized by natural actinide-transport processes.

The Historical Release Report (HRR; US DOE, 1992) indicates that Site soils have received radionuclide contamination from historical practices and legacy releases. Section 7.6 in Progress Report #3 (RMRS, 1997e) identified various events from the Site's production era which introduced radionuclides to Site drainages via both airborne and surface-water runoff pathways. As discussed in Section 7.5 of Progress Report #3 and Section 4.3 in this report, historical reports and reviews of soil/sediment data show diffuse low-level plutonium contamination of soils and sediments occurs in the SW093 drainage. The SW093 drainage includes various IHSSs and actinide source areas which could contribute radionuclides which produce elevated levels in surface water. The movement of contaminated soils and sediments in runoff could also result in localized deposits or diffuse contamination, depending on natural erosion and settling processes in the SW093 drainage.

Soil and sediment activities for samples in the SW093 drainage show a range of 0 - 100 pCi/g plutonium (see discussion in Section 4.3). The highest values are associated with soils near B779, B771/774, and B776. The maximum TSS measured to date at SW093 is 1,900 mg/L. These high TSS levels in conjunction with 0.1 pCi/g plutonium could produce activities of 0.19 pCi/L. Given the soil activities in the tributary drainage areas, the recent elevated activities at SW093 are possible from transport of diffuse contamination.

AME results suggest that transport of "dissolved" plutonium species is insignificant, whereas, physical transport of particulate-borne radionuclides is the primary component of plutonium mobilization. The ramifications of this finding, as related to specific mechanisms of transport, should be further refined by additional AME research currently underway. The surface-water Source Evaluation task team continues to collaborate with the AME Team and keeps current on the latest technical findings as well as recommended areas of research.

Section 4.2.2 of this report shows that the monitored SW093 sub-drainages all contribute actinide loads to SW093, further supporting the hypothesis of multiple or diffuse source areas. Data collected from monitoring locations GS32 and SW118 show the relative proportions of actinide load contributed to SW093 from each monitored sub-drainage.

The loading evaluation in Section 4.2.2 concludes that the GS32 and SW118 sub-drainages contribute an estimated 54% to 100% of the plutonium and 45% to 83% of the americium load reaching SW093. Specifically, the loading evaluation concludes that the GS32 sub-drainage contributes an estimated 50% to 100% and 40% to 77% of the estimated SW093 plutonium and americium loads, respectively. Although the loading evaluation indicates that the GS32 sub-drainage may be the primary source area, the evaluation of water-quality trends and correlations in Section 4.2.1 indicates that recent D&D activities for B779 have *not* resulted in increased actinide mobilization over historical levels. In other words, B779 D&D activities have not resulted in the creation of *new* source areas or increased particulate transport, but that recent GS32 elevated results occurred during relatively large runoff events. Therefore, the GS32 sub-drainage may constitute a significant source area for SW093, but this is likely to have been the case for some time, and not a recent development associated with recent D&D activities.

Other sub-drainages that are not directly monitored contribute the remaining plutonium and americium load measured at SW093. These other sub-drainages include:

- The North Walnut Creek reach between SW118 and SW093,
- A portion of the 700 Area including B771/774 and B776/777,
- A portion of the 500 Area including B559,
- A portion of the 300 Area including B371/374, and
- A portion of the 100 Area.

Several of these sub-drainages are targeted for Performance Monitoring in support of D&D projects, allowing for respective sub-drainage load estimation. However, many of the stormwater conveyance structures in the PA are aging, and monitoring would likely be inconclusive without significant ditch and culvert clean-out or repair.[32]

7.2. CONCLUSIONS

This section summarizes the findings of this Source Evaluation, and presents preliminary conclusions based on information presented and analyzed in this report.

[32] Visual field inspections indicate that many ditches and culverts are heavily sedimented (some are completely buried) severely compromising runoff routing (it appears that runoff would flow in various directions depending on the size of the precipitation event). Effective monitoring for source location requires that a sub-drainage be effectively defined based on expected runoff routing, and that flow be sufficiently channelized such that flow measurement and representative sampling can occur.

- Surface-water and soil/sediment sampling results suggest that one or more low-level distributed actinide source areas exist within the SW093 drainage. Further, surface-water activities have been of similar magnitudes for the last decade, suggesting source areas that originated as legacy contamination.

- Recent surface-water sampling results from Source Location monitoring stations have further refined the estimation of relative plutonium and americium load contributions to SW093 from upstream sub-drainage areas. These load estimations suggest that significant plutonium and americium source terms may exist in the B779 area (GS32 sub-drainage). Data indicate that these sources are legacy contamination as a result of past Site operations, and are *not* a result of current D&D activities.

- Load estimations and soil/sediment data also suggest that plutonium and americium source terms may exist in the following sub-drainage areas:

  1. North Walnut Creek reach between SW118 and SW093;
  2. A portion of the 700 Area including B771/774 and B776/777;
  3. A portion of the 500 Area including B559;
  4. A portion of the 300 Area including B371/374; and
  5. A portion of the 100 Area.

- Evaluation of readings from *in-situ*, water-quality monitoring probes indicates no unusual or unexpected conditions for WY99 to date. WY99 trends for all parameters are similar to those observed in WY98 and WY97, and real-time water-quality data cannot be linked to discrete upstream source areas.

- A review of current Site activities indicate no reason to suspect that D&D, ER Projects, excavation, or routine Site operations caused a release of plutonium or americium that resulted in the elevated activities measured at SW093.

- The elevated values observed at SW093 and other monitoring locations in the SW093 drainage are not being observed at the Ponds or downstream POCs.

7.3. RECOMMENDATIONS

Based on the findings of this Source Evaluation, the following recommendations are offered:

- The Site will continue the ongoing RFCA monitoring and source evaluation activities related to SW093 in an effort to further identify the location of sources.

- Specific mitigation activities in the GS32 sub-drainage are not warranted at this time because elevated results at SW093 are infrequent, B779 is scheduled for demolition this year, and downstream POCs have not shown elevated water-quality results. After B779 has been taken down, specific sub-drainage remediation/mitigation measures should be considered.

- Surface-water sampling location SW120 (located in the ditch between the North Perimeter Road and the Solar Ponds, 15 feet from GS32) should be upgraded with automated monitoring equipment as a Performance/Source Location monitoring location. The SW120 sub-drainage is predominantly the east side

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of the B771/774 complex. However, the culvert under the dirt road east of B774 and west of Solar Pond 207C is buried by sediment, and would need to be cleared before monitoring would be effective.

- Other Performance Monitoring locations in support of major building D&D operations would be useful for source location in the future. The Site in conjunction with Stakeholders is currently developing a long-term plan for Performance Monitoring based on the Closure schedule. However, extensive ditch and culvert clean-out is required before this monitoring would be effective.

- AME findings related to specific mechanisms of actinide transport should be further refined by additional AME research currently underway. The surface-water Source Evaluation task team will continue to collaborate regularly with the AME Team to remain up-to-date on the latest findings as well as to recommend possible areas of research. Any final remedy to reach closure of the IA will require a well founded understanding of the potential minimum activities or conditions that cause elevated concentrations of plutonium and americium in surface water. The findings of the AME, and associated projects such as the Site Water Balance, will help to solidify this understanding.

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NOTICE

All drawings located at the end of the document.

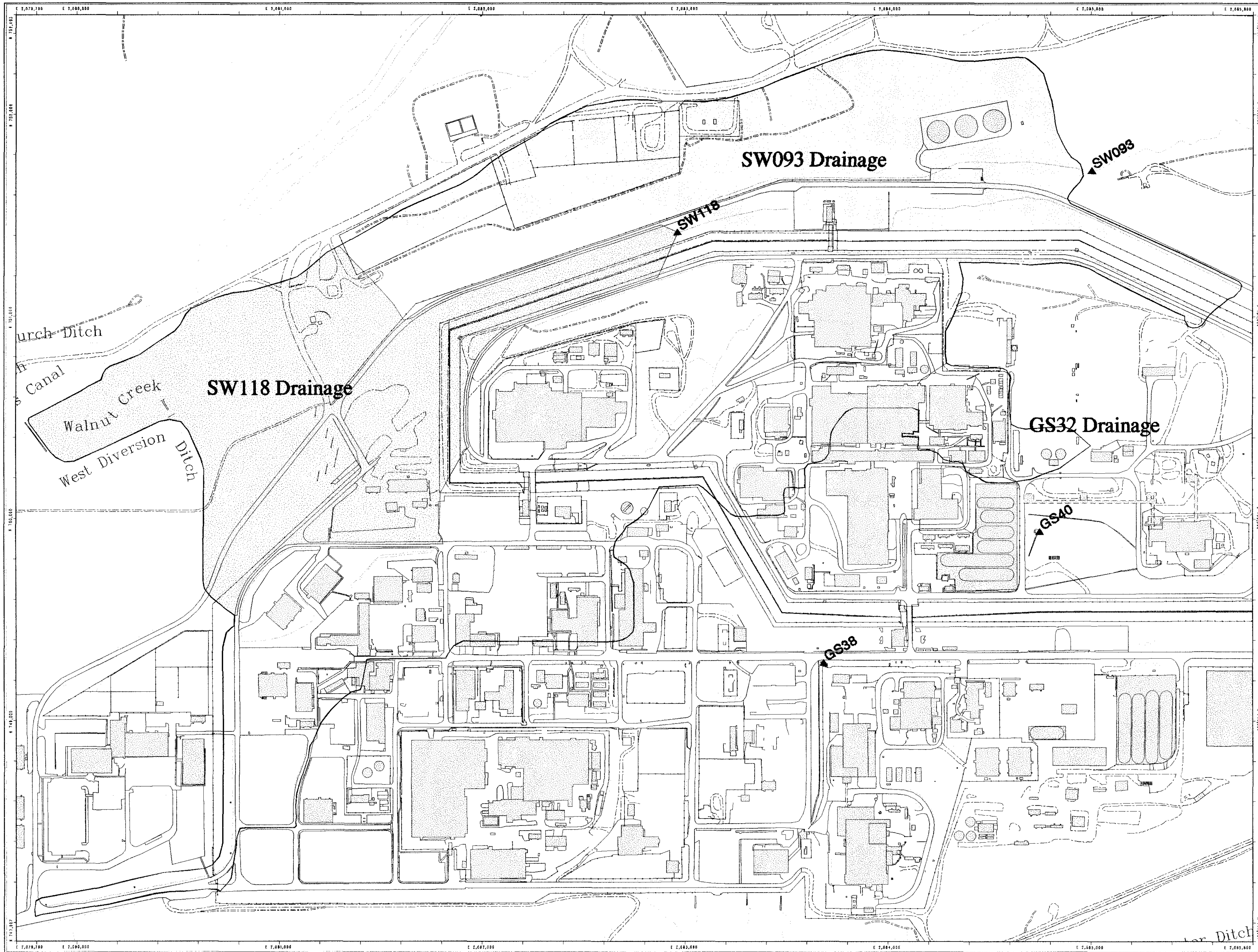

Figure 3-2

Selected Surface-Water Monitoring Locations Tributary to SW093

Legend

Monitoring Locations
- ▲ Point of Evaluation
- Performance
- ▲ Source Location

Drainage
- SW093 Drainage
- SW118 Drainage
- GS32 Drainage

Standard Map Features
- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Paved roads
- Dirt roads

DATA SOURCE: Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Scale = 1 : 5670
1 inch represents approximately 473 feet

100 0 200 400 Ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

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MAP ID: 99-0441

October 28, 1999

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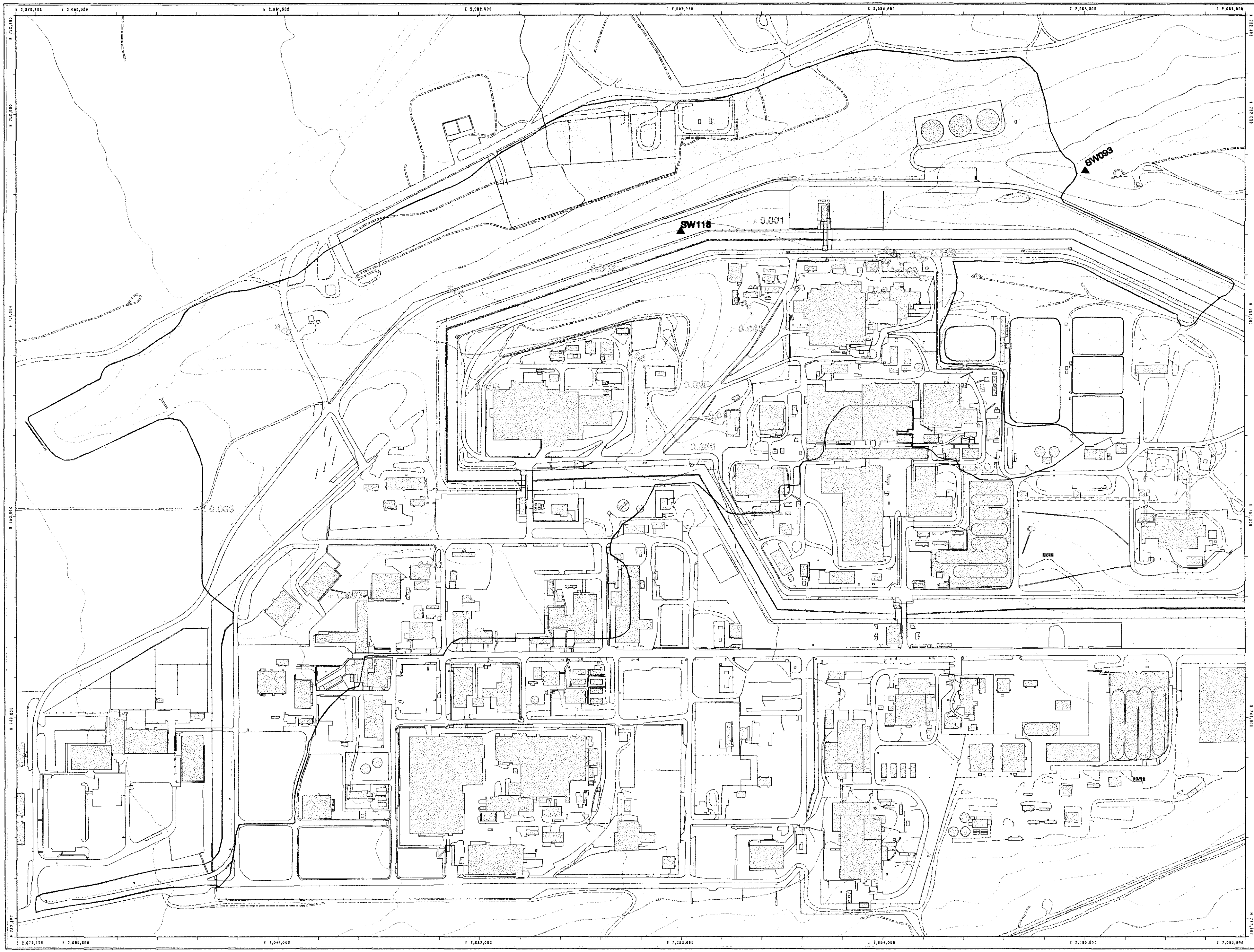
Figure 4-4

Surface Water Sampling Locations Tributary to SW093

Maximum Pu (pCi/L)



EXPLANATION

Monitoring Locations

- Point of Evaluation
- Performance
- Source Location
- Selected Surface Water Sampling Locations
- Selected Sediment Sampling Locations

Drainage

- SW093 Drainage

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution.
DEM post-processing performed by MK, Winter 1997.

Scale = 1 : 5670
1 inch represents approximately 473 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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November 01, 1999

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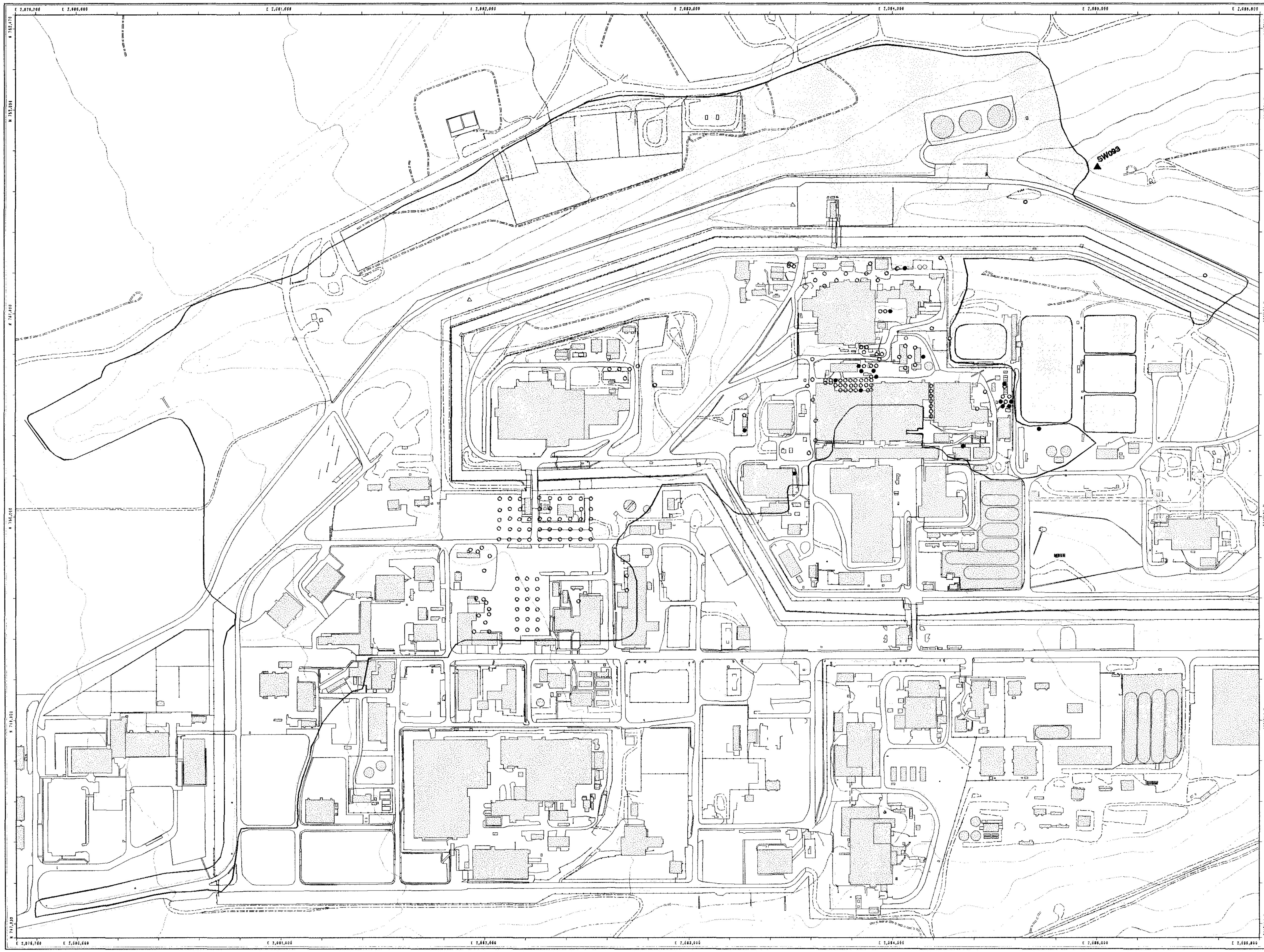

Figure 4-21

Surface Soil & Sediment Sampling Locations Tributary to SW093

Legend

Pu Activity pCi/g

- -0.1 - 0.1
- 0.1 - 1.0
- 1.0 - 10.0
- 10.0 - 100.0
- Greater than 100.0
- Point of Evaluation Monitoring Location
- Surface Soil Samples
- Sediment Samples

Drainage

- SW093 Drainage

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

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DEM post-processing performed by MK, Winter 1997.

Scale = 1 : 5620
1 inch represents approximately 468 feet

100 0 200 400 Ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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MAP ID: 2K-0023

October 26, 1999

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